Annual Report

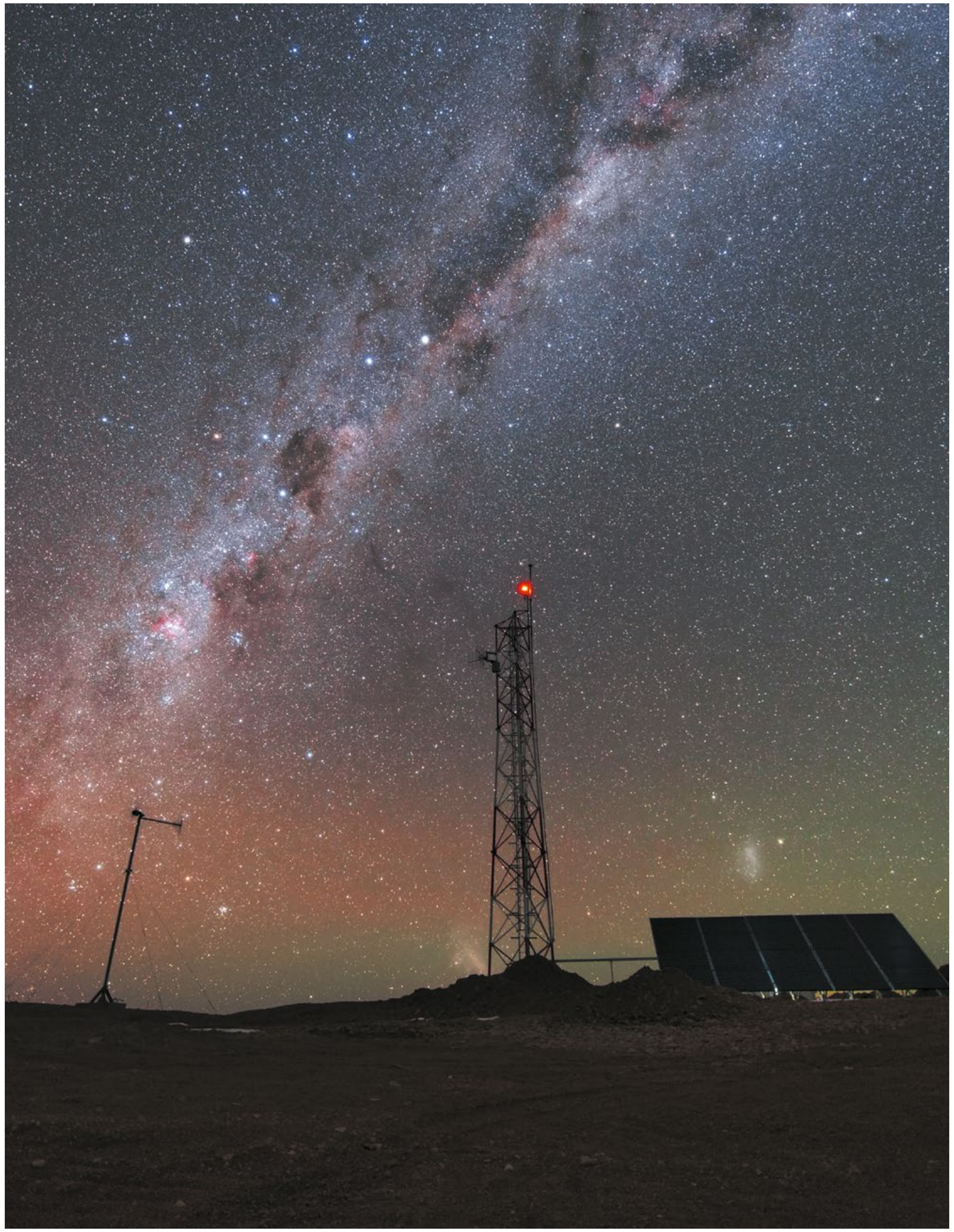
Sterrewacht Leiden

Research Institute Leiden Observatory

Onderzoeksinstituut Sterrewacht Leiden

Index

FOREWORD



Dear Reader

For many reasons 2019 was a special year. First and foremost, it was the year of the celebration of the 100th anniversary of the International Astronomical Union. Skilfully led by Ewine van Dishoeck, IAU president, many IAU 100 events were organized. With the theme 'Under One Sky', 5000 activities were held in 143 countries reaching over 100 million people. The central hub was the Secretariat located at Leiden Observatory with Jorge Rivero González and Pedro Russo as key players. The exhibition at the old observatory 'Above and Beyond: Making Sense of the Universe for 100 Years' showcased some of the most significant and surprising astronomical breakthroughs. While not directly linked to IAU 100, as a guest curator Ewine also created an impressive exhibition at Rijksmuseum Boerhaave titled 'Cosmos: Art & Knowledge'. It displayed a large variety of objects, such as a moon rock from the Apollo 17 mission, antique globes and the painting "*the cosmos*" by Kandinsky. On 17 December 2019 in the *Stadsgehoorzaal* in Leiden, a grandiose Astronomy Gala was held. It not only marked IAU 100, but also the 20th anniversary of the Netherlands Research School for Astronomy (NOVA). With King Willem-Alexander as the guest of honour, Dutch astronomers presented our scientific discoveries in lively and often spectacular ways.

Scientifically we were extremely productive, with well over 700 refereed publications. It was good to see that the books "Jan Hendrik Oort - Master of the Galactic System" by Piet van der Kruit and "De zaak Zonnestelsel" by Martijn van Calmthout and Simon Portegies Zwart were published. On a personal note, I was very happy that the LOFAR survey team made considerable progress and published a special issue of Astronomy and Astrophysics that attracted a lot of attention. To quote the response of Chris Evans (known for being Captain America in the Marvel movies - @ChrisEvans | 13,760,210 followers): *'I can't even describe how much I love this.'* But the real 'big bang' in 2020 was the publication of the picture of the black hole in M87, which has now been seen by a significant fraction of the world population. We are proud of our local people (Remo Tilanus, Huib Jan van Langevelde, Wilfried Boland and Ciriaco Goddi) that contributed to this spectacular result and who are now co-recipients of the Breakthrough Prize.

This year's Oort lecture was presented by Prof. Connie Aerts. It was titled 'Starquakes and Exoplanets in our Milky Way' and gave a lively account of asteroseismology and how this informs us about exoplanets and their habitability.

Student numbers continued to rise. With 115 freshmen started in astronomy, the total number of bachelor students was well over 250. In 2019 there were 104 MSc students, including 35 women and 54 of foreign nationality. Also the number of PhDs awarded – 23 – was an all-time high. As I have the privilege of being on every reading committee, I can say with pride that each of these theses is a very significant contribution to astronomy. Congratulations to all! It was very gratifying to learn that 4 PhD students were awarded international prizes. The International Astronomical Union (IAU) awards the IAU PhD Prizes each year to the best PhD candidates in their field - Niels Ligterink won in the division Facilities, Technology and Data Science, and Jorryt Matthee in the division Galaxies and Cosmology. Jorryt also won the C.J. Kok Jury Prize for best thesis at our Faculty of Science. Cameron Mackie was awarded both the Dissertation prize of the Laboratory Astrophysics division of the American Astronomical Society and the Dissertation prize of the Astrochemistry subdivision of the American Chemical Society for his thesis, and Jos de Boer received the Chesneau prize, which is awarded to the best dissertation in the field of high angular resolution.

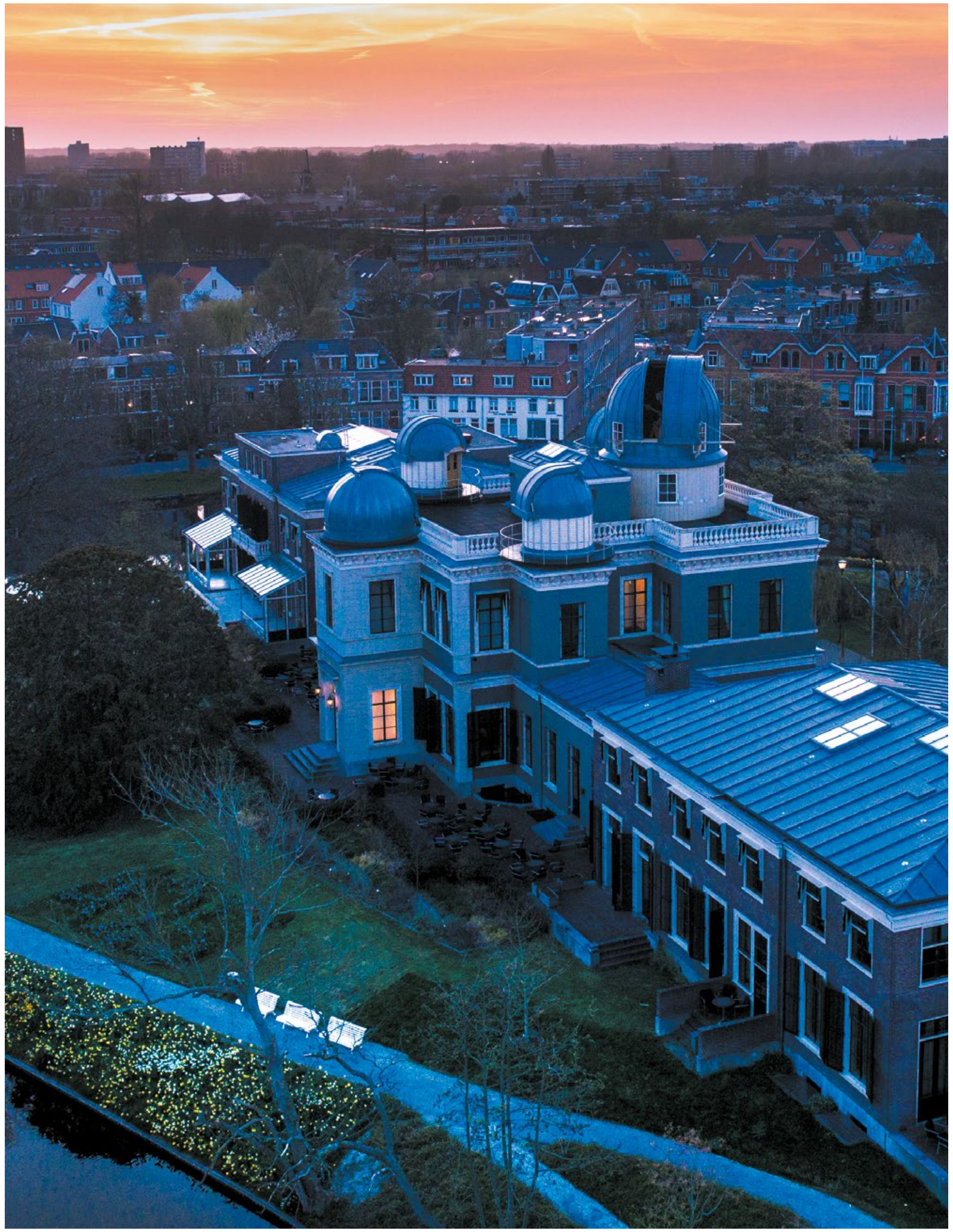
A number of prestigious honours and prizes were received by several members of our staff. Anthony Brown gave the Spitzer Lectures at Princeton, Ewine van Dishoeck was awarded the Schwarzschild Medal and received an honorary doctorate from the University of Geneva and Ignas Snellen received the Hans Sigrist Prize from the University of Bern.

Huub Röttgering,
Director

The year was also marked by tragedy. On January 17 our PhD student Maolin Zhang tragically died in a house fire in Hillegom – an immeasurable loss. The silent walk and the memorial event at the Academy building with his father and two nephews present gave some support. It was heartwarming that the crowdfunding to support the parents was such a success. We also mourned the loss of Professor Lodewijk Woltjer, who passed away on 25 August 2019 and made a decisive impact on global astronomy. It was his vision and determination that gave us the VLT.

Indeed 2019 was a special year, with many ups and a few serious downs. However, I am now writing this during the Corona lockdown and realise that 2020 will be challenging and that we all need to work towards the *'nieuw normaal'*. This also means that we need to take an active role in the current climate crisis and it is good that in this yearly report Leo Burtscher shares his thoughts on this.

LEIDEN OBSERVATORY



The mission of Leiden Observatory is to carry out world class astronomical research, provide education at the 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.

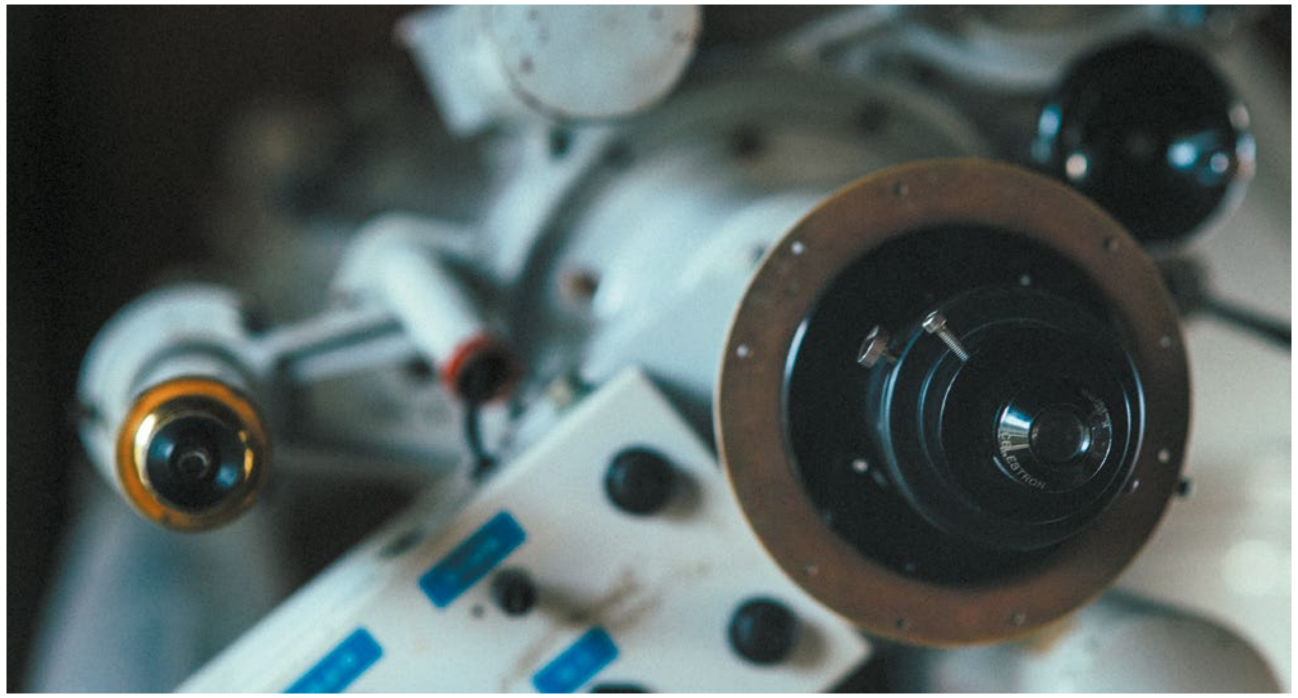
The **Observatory** and its **people**

Sterrewacht Leiden was founded by Leiden University in 1633 to house the quadrant of Snellius, making it the oldest operating university observatory in the world. While originally located at the main Faculty Building of the university, a purpose-built observatory was constructed in the university's botanical gardens in 1860. Since the mid-1970s the institute has been located within the campus of the Faculty of Science. A long list of eminent astronomers has populated the Sterrewacht, including Profs. Willem de Sitter, Ejnar Hertzsprung, Jan Oort, Adriaan Blaauw, and Henk van de Hulst. Currently, Leiden Observatory is proud to be one of the largest and top astronomical research institutes in Europe. It has 25 scientific staff members, about 80 postdoctoral researchers, 90 PhD students, 104 Masters students and 265 Bachelor students. Among its professors are three Dutch Spinoza Prize winners: van Dishoek, Franx and Tielens. Prof. Tim de Zeeuw was the Director General of the European Southern Observatory – the largest observatory in the world, and Prof. Ewine van Dishoeck is the president of the International Astronomical Union (2018-2021).

Research and Technology

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



Bachelor and 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 265 students, and provides a broad basis in astronomy, with important components in physics, mathematics, and informatics. The two year masters in astronomy is currently followed by about 104 students. Since it is fully taught in English it is also very popular among non-Dutch students. The masters not only prepares students for a scientific path, but also launches careers in business or industry.

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

Public Engagement

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

Calendar of Events 2019

JANUARY

PhD student Maolin Zhang tragically dies in house fire [17]

FEBRUARY

PhD interviews [15]

MARCH

Cameron Mackie awarded the Dissertation prize of the Laboratory Astrophysics division of the AAS and the Dissertation prize of the Astrochemistry subdivision of the ACS [21]

APRIL

Astronomers capture first image of a black hole [10]

100 years of the IAU [11]

Oort Lecture, Conny Aerts [17]

MAY

Anthony Brown gives Spitzer Lectures at Princeton [17]

Jos de Boer receives Chesneau Prize for best dissertation [20]

NAC in Paterswolde [27]

JUNE

Prof. Conny Aerts delivers the Oort PhD lectures on Asteroseismology [12-14]

Sterrewacht BBQ [21]

JULY

Solar Eclipse Expedition to Chile [02]

AUGUST

Leiden Science Run [01]

Oort Biography Book Launch with Piet van der Kruit [29]

SEPTEMBER

Ronald Stark is new Executive Director of NOVA [01]

Ewine van Dishoeck awarded Schwarzschild Medal [11]

Sterrewacht Science Day [13]

Gala van Sterrenkunde [17]

Breakthrough Prize for first picture of black hole [23]

OCTOBER

Ewine van Dishoeck receives honorary doctorate from University of Geneva [15]

NOVEMBER

PhD Introductory Days [27]

DECEMBER

Sinterklaas celebration [05]

Hans Sigrist Prize for Ignas Snellen [07]

Jorryt Matthee wins the C.J. Kok Jury Prize for best thesis at the Faculty of Science [09]

Super Christmas Borrel [13]

GALA VAN STERRENKUNDE

Photos: Bob Bronshoff/NOVA | Text: Linda van Putten

At the Astronomy Gala on 17 December in the concert hall in Leiden, astronomers looked back, but above all ahead. With King Willem-Alexander as guest of honour.

The gala was to mark the 100th anniversary of the International Astronomical Union (IAU) and the 20th anniversary of the Netherlands Research School for Astronomy (NOVA). Ewine van Dishoeck has a key role in both organisations: she is scientific director of NOVA and president of the IAU, which represents around 13,500 astronomers from over 100 countries. She hosted the gala in a packed concert hall together with Jim Jansen, editor-in-chief of the Dutch version of New Scientist.

Extremely Large Telescope

Alongside highlights such as the first moon landing and the spectacular first photo of a black hole, there was much speculation about that one pressing question: when are we going to discover extraterrestrial life? 'We are the first generation to possess the technology that can answer that question,' said Van Dishoeck. The ELT, or Extremely Large Telescope, will be completed in about six years' time. This exceptionally powerful telescope the size of a football stadium is being built in the Atacama Desert in Chile. Another astronomer from Leiden, Tim de Zeeuw, was one of the architects of the ELT. He started work on this the largest telescope in the world in his years as director-general of the European Southern Observatory.

Tour for the King

King Willem-Alexander was impressed by the discoveries presented. He looked at displays of telescopes and instruments and spoke to a number of researchers. He was also given a tour of an exhibition about one century of astronomy and space research.

First photo of a black hole

Celebrated astronomers from home and abroad spoke, often with an injection of humour, about their research. Heino Falcke, for instance, who is Professor of Radio Astronomy in Nijmegen. He is one of the initiators of the project to take photos of black holes with telescopes in various parts of the world. His efforts and those of hundreds of his colleagues have been rewarded. The first photo ever of a black hole ('it looks like a doughnut') hit the world headlines this year.

Baby photo of the universe

Presenter Jim Jansen asked what the next iconic moment would be. Not finding extraterrestrial life because that will take some time. Most of the astronomers agreed that the younger generation in the room would live to see this discovery but the older one probably wouldn't. Because the new telescopes are making it increasingly easy to follow the evolution of the universe. Leiden astronomer Frans Snik spoke about how he and his team are developing innovative technology for the next generations of telescopes.

GALA VAN STERRENKUNDE

Earth looked like Mars

The mysteries of the universe are mostly unravelled by closely studying the Earth itself. For its first billion years Earth was like Mars, said astrobiologist Inge Loes ten Kate from Utrecht University. To gain a better idea of possible extraterrestrial life, she is researching how life on Earth developed. It is not just researchers but also 'normal' citizens on Earth who benefit from technological developments in astronomy, Leiden astronomer Pedro Russo emphasised. Innovations like wifi or advanced MRI images for detecting disease are thanks in part to astronomy, and it is easier to discover environmental pollution with the technology from this discipline. Said Russo, 'Astronomy can help protect our fragile planet.'

Spaceship

Taking better care of the Earth was also the message of Leiden astronomer Vincent Icke, who stepped into the shoes of one of our exoplanet neighbours as it looked pityingly at life on Earth. Then it was time for astronaut André Kuipers to give an evocative description of his time in space. He ended the gala with a warning, 'We're a spaceship with limited supplies.'

DIVERSITY

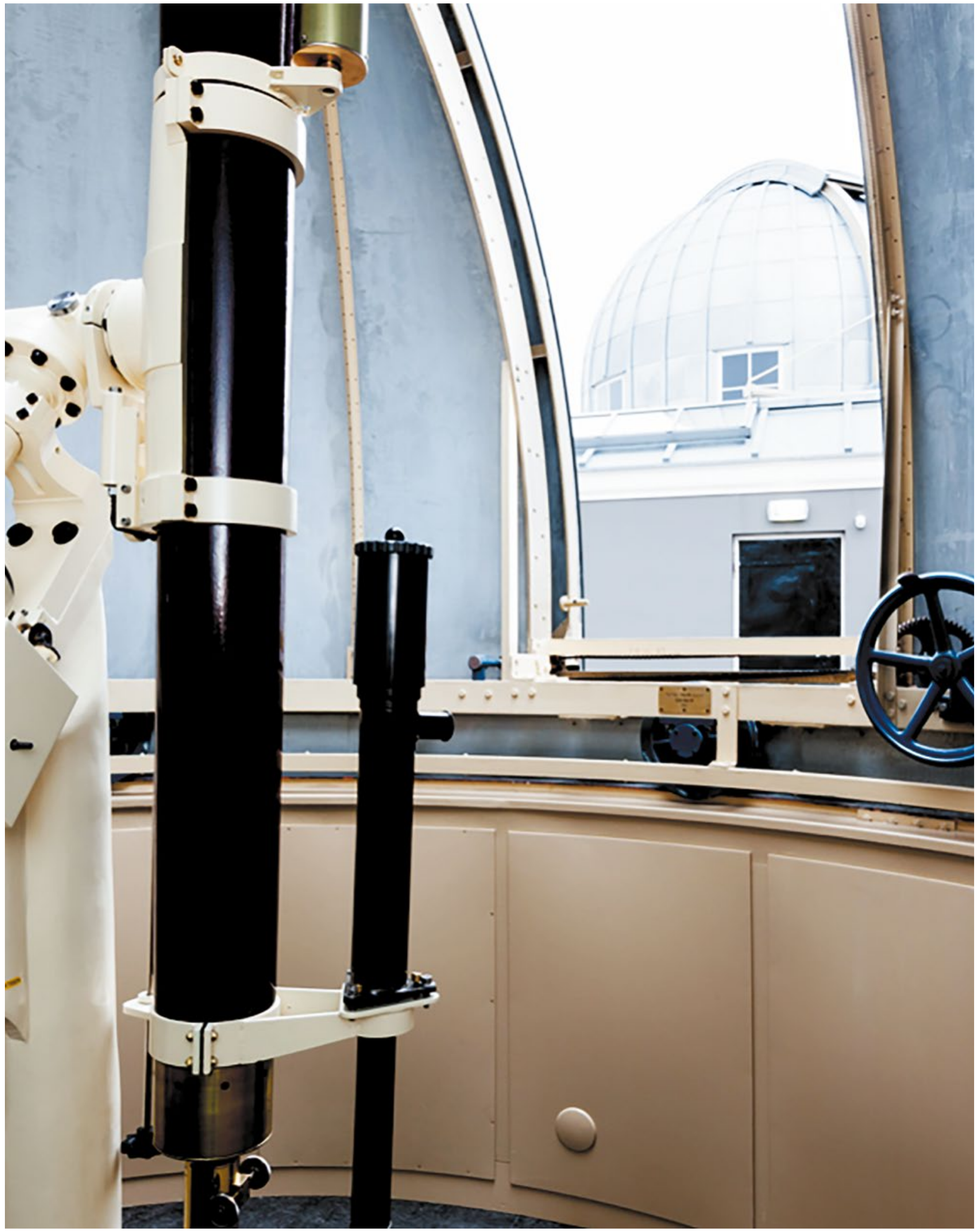
Jacqueline Hodge

2019 was a busy year for the Diversity and Inclusion Committee. We kicked off the year by conducting an Observatory-wide survey designed to assess the well-being of the department and understand how to further improve it.

The findings were presented at a general seminar and discussed further at targeted meetings. These discussions led to a concrete list of both short – and long-term actionable items for improving the overall well-being of our department, a number of which are already being implemented.

In addition to the various discussions motivated by the survey, the department hosted a number of diversity and inclusion-related events. In April, we welcomed Prof. Marieke van der Brink from Radboud University, who gave a seminar on gender and diversity in academia. In May, Dr. Sarah Rugheimer (Oxford University) led an interactive workshop on imposter syndrome. Finally, in June, the scientific staff attended an implicit bias workshop led by organizational leadership experts Liesbeth Halbertsma and Michiel Zeegers.

ASTRONOMY AND THE CLIMATE CRISIS



Leo Burtscher

When I last boarded a plane, in December 2018, for a scientific conference in Chile, my "flygskam" was enormous and I vowed not to take another flight unless it was absolutely necessary. For the entire year 2019 it turned out that I didn't have to: A mix of videoconferences, long day trips on trains and occasional night trains, in combination with the geographic distribution of my main collaborators as well as my existing network and position, made it possible to avoid flying for the entire year of 2019. It did require quite some organisation within my family since e.g. a train trip to ESO Garching obviously takes longer than the corresponding flight. It did not, however, feel like a sacrifice. I was able to spend the time on the train quite well for working, reading, relaxing, much more so than on a plane.

Reducing our air miles is important in two ways: It shows that we understand the urgency of the climate crisis (see graphic "climate bucket" in Figure 1) and makes us credible actors in demanding change. It also demonstrates that astronomical research and collaboration can continue without (frequent, intercontinental) in-person meetings – an almost trivial statement now that we all have to work and meet remotely due to the global Covid-19 pandemic.

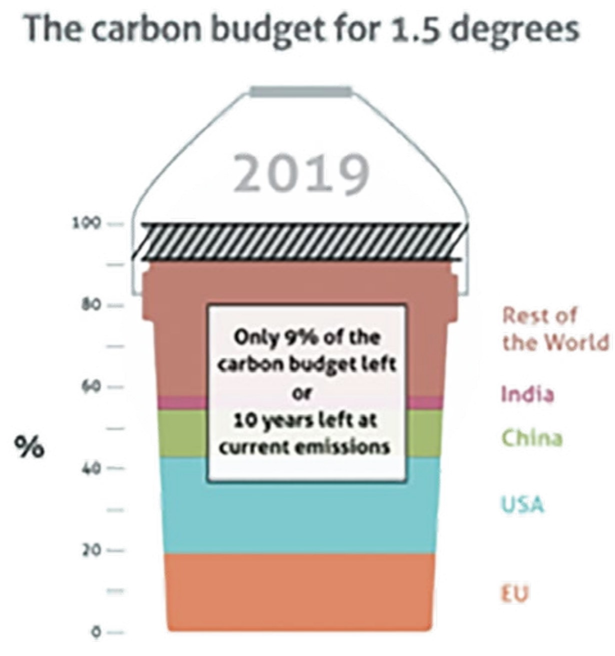


Figure 1: The global carbon budget for anthropogenic CO2 emissions is nearly full. At the 2019 rate of emissions, the bucket will flow over after just 10 more years, making it unlikely to reach the 1.5 degree goal of the Paris agreement and risk severe changes to the Earth's climate. Visualisation and more information, including scientific references: globalcarbonproject.org & University of East Anglia

The Corona crisis also lets us feel the magnitude of the change that is coming. If some of the (travel) restrictions are still in place until the end of the year 2020, the drop in annual CO2 emissions in 2020 will only be 7^{+6}_{-4} % [1]. This is roughly the reduction we need to achieve from now on **every year** to still reach the Paris climate goals.

To understand how we can most effectively reduce our own emissions, it is important to understand our carbon footprint beyond travel, however. Fortunately, two astronomical institutes have recently performed this exercise.

The Max-Planck-Institute for Astronomy in Heidelberg, in many ways comparable to Leiden Observatory, calculated their carbon emissions for the year 2018 [2] and found that 47% of the total output of 2726 t (CO_2 equivalent) comes from flying, mostly long-distance. Other major factors are electricity from both on-site and off-site facilities (e.g. supercomputing centres) that accounted for 29% of the total CO_2 emissions and heating (16%). ESO, who have undergone a full carbon audit [3] and are currently assessing its results, have estimated their total emissions as 28 kt CO_2. Their largest source of emissions is the production of electricity from fossil fuels (41% – more than half of it for Paranal), followed by purchases (30%) and business travel (10%). ALMA was not included in their calculation. Several improvements have already been made inside ESO to reduce their carbon footprint or are underway [4], but power consumption will continue to grow. While the operation of the VLT requires about 10 GWh/year of electrical energy, the ELT will require more than double [5].

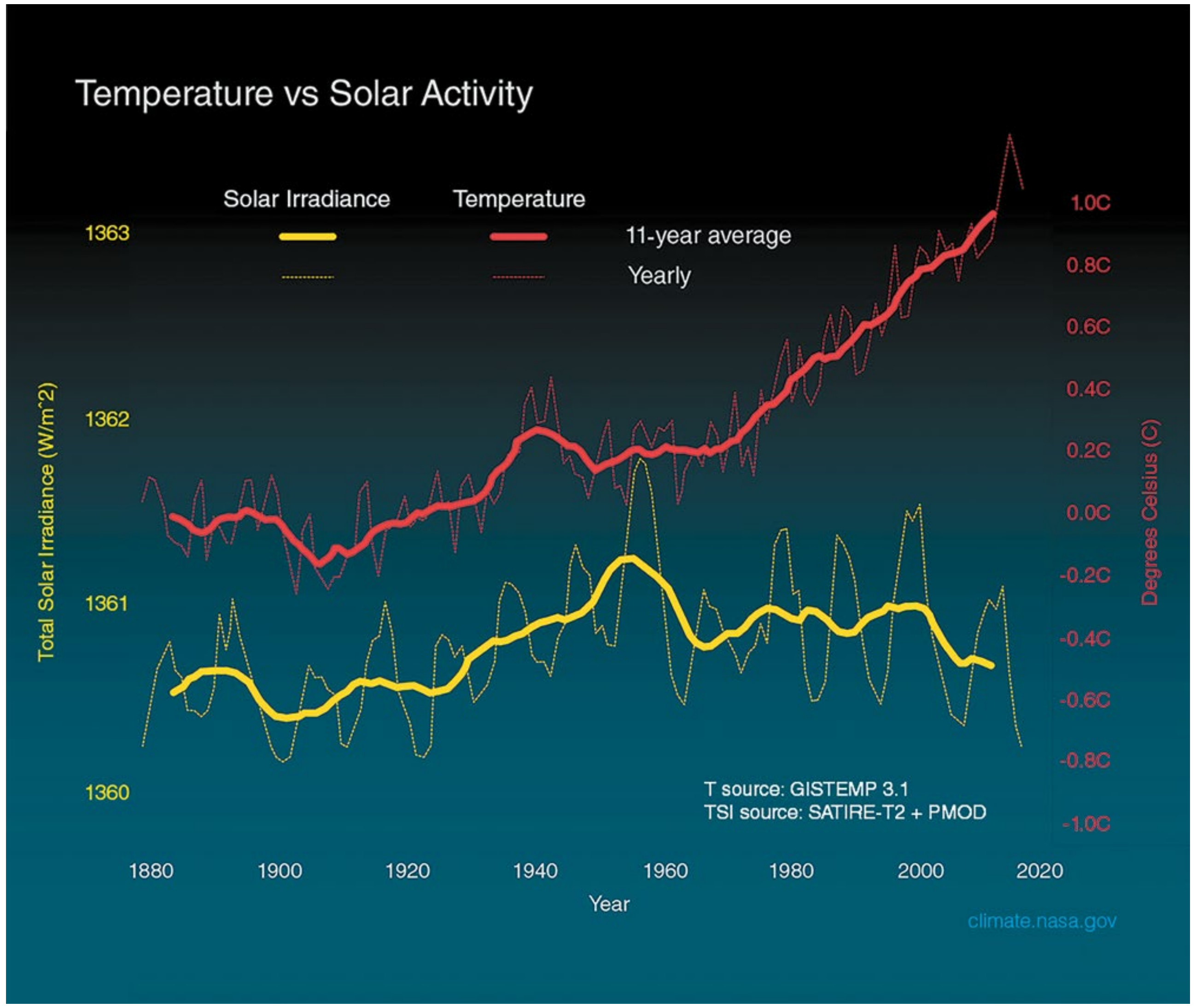


Figure 2: Global mean surface temperature vs. solar activity. (Image: NASA/JPL-Caltech)

I believe we should strive to reduce our own carbon footprint as much as possible, both for moral reasons and as a message in itself that we are taking the climate crisis seriously. We should not, however, stop there, since we can do much more: Many of us are avid science communicators and we can use our abilities and our reach not just to highlight the latest astrophysical results, but also for the better of humanity.

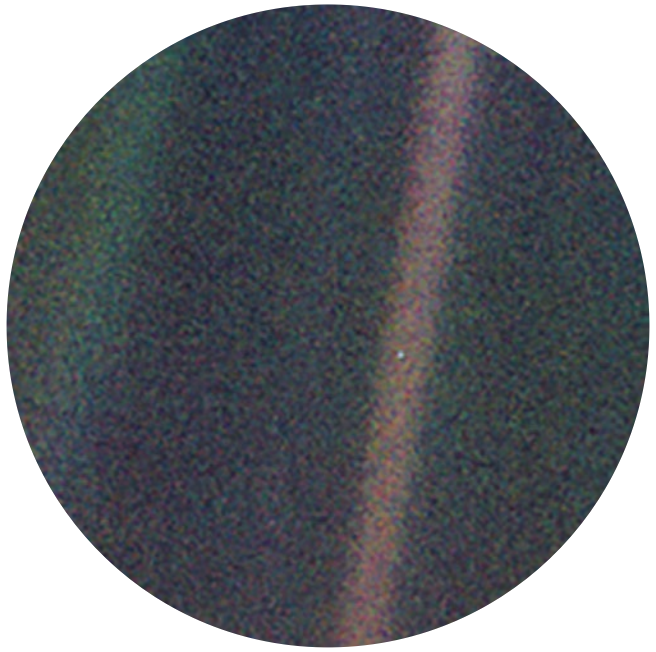


Figure 3: Earth as seen from behind Neptune's orbit: A pale blue dot. (Cropped; Image: NASA)

Astronomical climate communication can be on a number of aspects:

We can convey (astronomical) climate **facts**, such as the (non-)relation between the sun's activity and the recent warming of the Earth (see Figure 2) and explain how both measurements come about. There is generally a lot of interest – and trust – in astronomical discoveries and we can use this neutral standpoint to explain that the scientific method (and technology) telling us about the coming climate crisis is exactly the same as the one that brings us a picture of a super-massive black hole. We can also back the climate protesters' statement "There is no planet B" by embedding statements about the uniqueness of Earth in our talks about exoplanets. Rather than claiming that we search for "Earth 2.0", we should communicate that we have nowhere else to go and need to protect our only home.

Secondly, we can bring perspective. One of the most influential astronomical pictures has been the image of the Earth taken by the Voyager 1 space probe from behind Neptune's orbit (see Figure 3). I have not yet met a person who was not thrilled when shown this image of Earth as a "Pale Blue Dot". The image conveys a sense of uniqueness of our planet, a feeling of global citizenship arises and it becomes clear that we can only protect humankind by working together.

Finally, many of our pictures and movies of the wonders of the universe are breathtakingly beautiful. It is known from psychological research that awe promotes empathy and altruism [6] and may thus help to convince the public of the necessary actions to avoid climate breakdown.

References:

- [1] Le Quéré, Jackson, Jones et al. „Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement", Nat. Clim. Chang. (2020), https://doi.org/10.1038/s41558-020-0797-x
- [2] MPIA Carbon budget, Jahnke et al. (in prep.)
- [3] ESO carbon audit, Arsenault et al. & carbone4.com (in prep.)
- [4] https://www.eso.org/public/about-eso/green/?lang
- [5] Filippi et al. (2016), SPIE
- [6] Piff, Dietze, Feinberg et al. „Awe, the Small Self, and Prosocial Behavior", Jour. of Pers. and Soc. Psych. (2015), 108, 6, 883

RESEARCH HIGHLIGHTS

Unveiling the initial conditions for planet formation

Merel van 't Hoff

In the last 25 years, more than 4000 planets have been discovered around stars other than the Sun. These planetary systems display a large diversity, but our Solar System seems atypical. Whether a planet like Earth, and ultimately life, is uncommon, can be addressed by studying the material around young stars that eventually make up planets. On the one hand, comparing the composition of planetary building blocks to the composition of Solar System comets –remnants of the young Solar System – can tell whether the initial conditions for the formation of the Solar System are unique or very common. On the other hand, using this information in planet-formation models can predict the likelihood of forming an Earth-like planet under given conditions. Moreover, studying the chemical complexity at the onset of planet formation can tell us whether the building blocks for life are formed in space, and possibly delivered to young planets by cometary bodies, or whether life has to start from very simple molecules on a planetary surface.

Planet formation was originally thought to start in disks of gas and dust around pre-main sequence stars, so-called protoplanetary disks. These disks have therefore been studied extensively, in particular with the Atacama Large Millimeter/submillimeter Array (ALMA). However, more and more studies, both of individual systems (including the Solar System) as well as surveys of star-forming regions, are now providing evidence that planet formation starts much earlier: the first steps are likely to take place when the disk is still embedded in an envelope of infalling material (Figure 1). The study of young disks has long been hampered due to their embedded nature. ALMA now provides the spatial resolution and sensitivity to study these disks at planetary-system scales, and thus allows us to address whether the structure and composition of young disks are similar to those of mature protoplanetary disks.

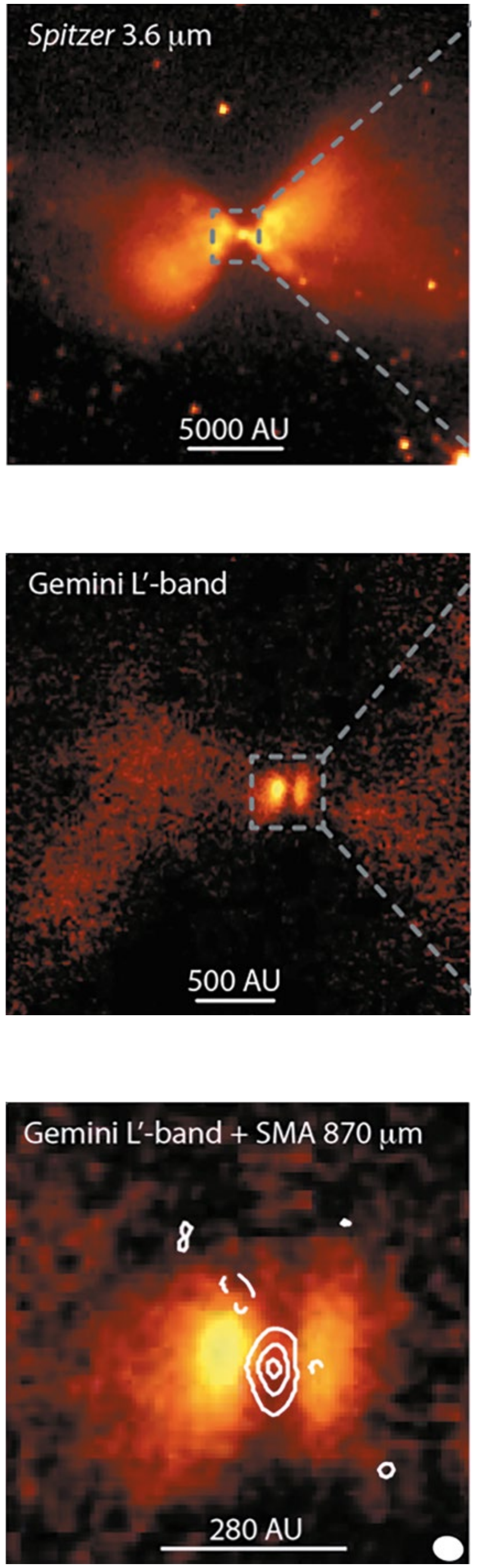


Figure 1: Scattered light observations of L1527 at different spatial scales. The central dark lane is the shadow of the young disk, which becomes visible at mm wavelengths (white contours in right panel). Images adapted from Tobin et al. (2010, 2013).

A crucial parameter for planet formation is temperature, because it governs the resistance of the gas to gravitational instability – a possible way to form giant planets – and sets the chemical composition of the planet-forming material. The effect of temperature on the chemical composition can be most easily seen through the freeze out of molecules onto dust grains when the temperature drops below their species-dependent freeze-out temperature. The radial temperature gradient in the disk therefore results in the sequential freeze out of molecules, at their so-called snowlines, and hence in radial variations in the composition of the planet-forming material (for example, the elemental C/O-ratio).

One of the most important snowlines is the CO snowline, because CO is the second most abundant molecule in disks (after H2) and because CO ice is the starting point for the formation of many complex molecules that are the precursors of prebiotic molecules. In addition, due to the low freeze-out temperature of CO (approximately 20 K), the CO snowline is located relatively far away from the star and therefore observationally the most accessible snowline. Studies of mature protoplanetary disks have located the CO snowline at radii between 20 and 100 AU. The general picture that has emerged shows thus that mature disks have a large cold (< 20 K) outer region where CO is frozen out.

To see whether this is the same in younger disks, thus at the onset of planet formation, van 't Hoff et al. (2018a) studied the embedded disk L1527 with ALMA. Unlike mature disks, L1527 shows no signs of CO freeze out. A follow-up study of four other young disks suggests that young disks are indeed warmer than their more-evolved counterparts because signs of CO freeze out are only observed in the outer part (> 100 AU) of a disk that has only very little envelope material left (van 't Hoff, PhD thesis). Observations of formaldehyde (H_2CO) allow to further constrain the temperature structure: absence of H_2CO emission from the disk midplane suggests that the temperature lies between 20 and 50 K, that is, warm enough for CO to remain in the gas but cold enough for H_2CO to freeze out (Figure 2, left panels).

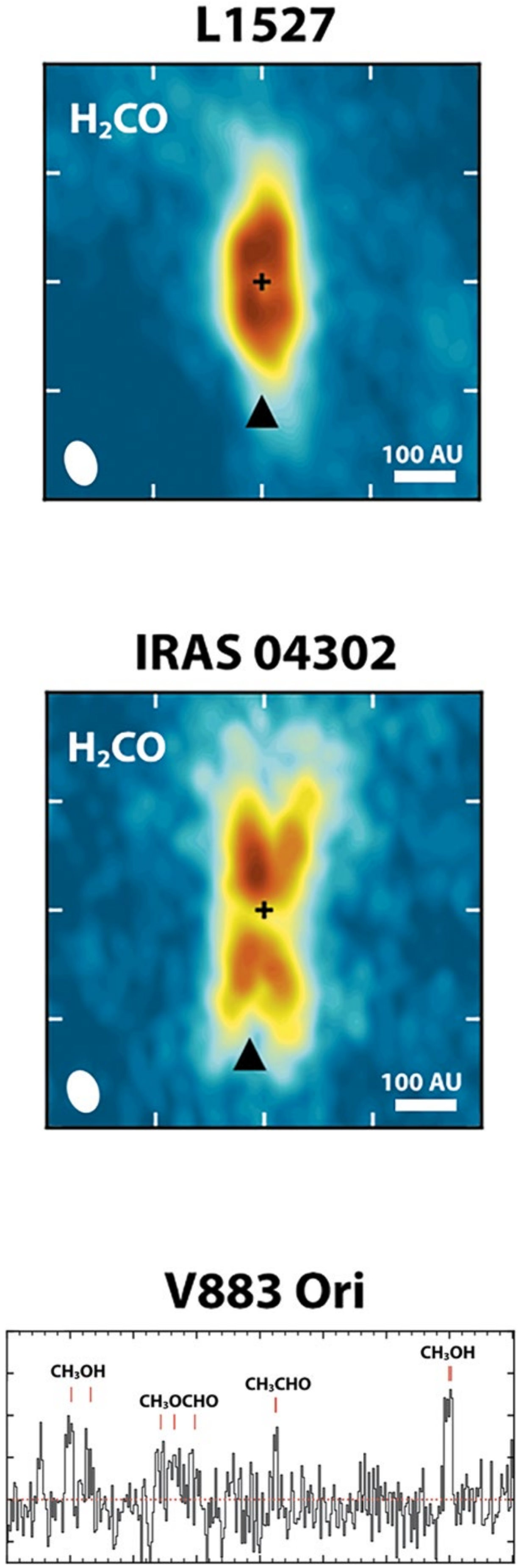


Figure 2: Formaldehyde (H_2CO) observations with ALMA toward the young disks L1527 and IRAS 04302 reveal that the midplane of the more evolved disk around IRAS 04302 is colder than that of L1527 such that H2CO freezes out (marked with black triangle). The disk around the outbursting young star V883 Ori is heated enough to liberate complex molecules from the ice. Images adapted from van 't Hoff et al. (2018b, PhD thesis).

These results are consistent with model predictions of embedded disks being warmer due to the higher accretion rates of material onto the protostar during this phase. As the accretion rate decreases from the protostellar to protoplanetary disk stage, the temperature of the circumstellar material is expected to drop as well during protostellar evolution. Analysis of thioformaldehyde (H_2CS) toward IRAS 16293A, a probably less-evolved protostar with a higher accretion rate, by van 't Hoff et al. (2020) shows that the temperature in the inner 150 AU is indeed roughly 100 K higher than in the young L1527 disk (Figure 3).

Temperatures above 100 K in the inner 150 AU naturally explains observations of many complex organic molecules toward IRAS16293A: many of these molecules freeze out at temperatures below 100 K. These results then also suggest that, although young disks are warmer than mature disks, observing complex molecules will still be difficult because they are expected to be frozen out in most of the disk (see Figure 3). However, van 't Hoff et al. (2018b) showed that when a young star undergoes a burst of accretion, the embedded disk can be heated enough to liberate complex molecules from the dust grains, allowing the chemical complexity of the planet-forming material to be probed (Figure 2, right panel).

Small molecules like CO and H_2CO thus provide information about the temperature structure of young disks, and hence the elemental composition of both the gas and ice from which planets will form, while larger molecules provide an insight into the level of chemical complexity that is present. Future ALMA observations of these molecules in a larger sample of young disks will thus establish the initial conditions for planet formation.

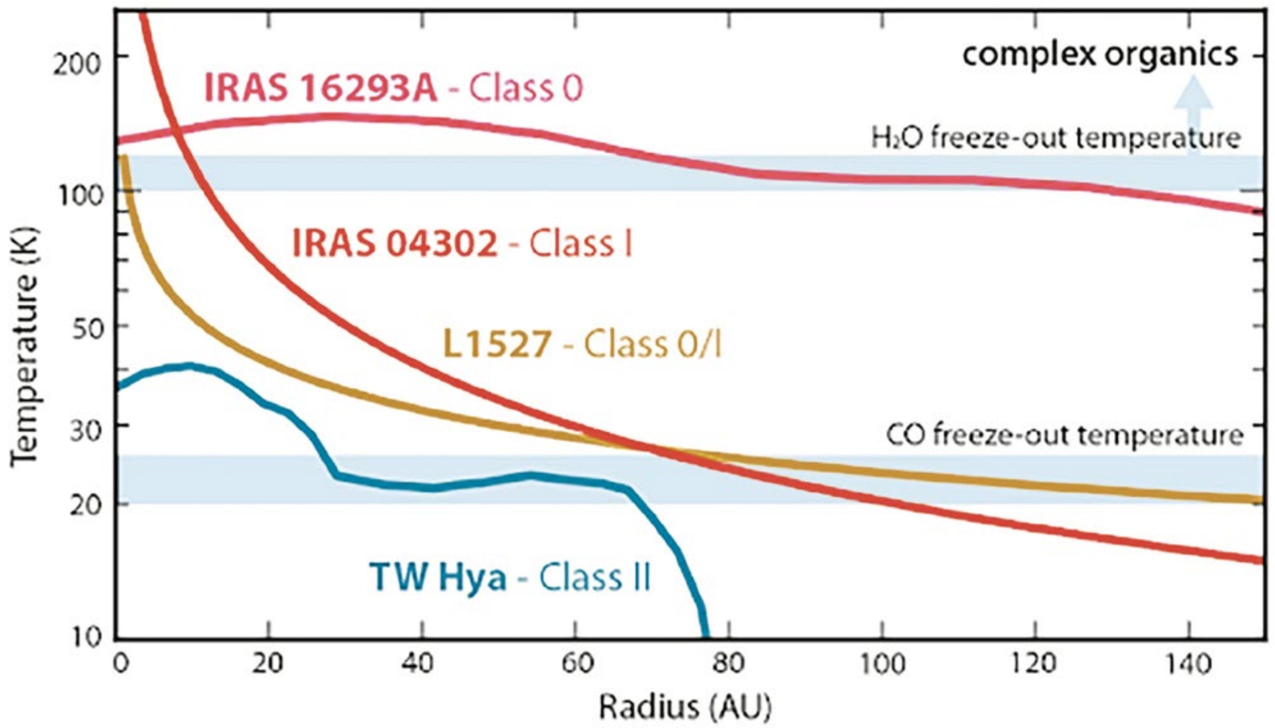


Figure 3: Radial temperature profiles for disks at different evolutionary stages suggesting that the temperature decreases as the system evolves and the rate at which material accretes onto the star decreases. Data from Schwarz et al. (2016) and van 't Hoff et al. (2018a, 2020 and PhD thesis).

Dutch technology at high-frequencies

Alvaro Hacar

Most of the stars in the Universe originate in compact stellar associations, known as clusters. Clusters are also the birthplaces of high-mass stars. Understanding the origin of these stellar systems is therefore of crucial importance for our description of the star formation process across Cosmic Times.

Star-formation occurs under extreme physical conditions inside these clusters. Massive systems, such as globular clusters, contain up to millions of stars in a radius of a few parsecs. Clusters are the subject of strong disruptive effects generated by the powerful feedback produced by their embedded stellar populations. These compact systems also form and evolve rapidly in short timescales of one million years. Theoretical calculations indicate that these massive clusters originate from gas at extremely high densities. Despite continued observations through the previous decades, the observational detection of these extremely dense star-forming materials in clusters remained elusive until today.

According to radiative transfer calculations, the extreme gas densities predicted in some massive clusters are expected to excite many of the molecules in these regions into high energy states. This unique observational characteristic predicts the bright emission of different molecular tracers at frequencies above 500 GHz. Observing these high-frequencies from the ground is, however, far from trivial. This submillimeter radiation is rapidly absorbed by the water vapor present in our own atmosphere. Usually restricted to space or stratospheric instruments such as Herschel or SOFIA, these frequencies can be only observed from the ground under from the driest places on Earth and under exceptional weather conditions (with precipitable water vapor levels less than 0.5mm).

The new Swedish-ESO PI instrument for APEX (SEPIA) is opening a new window on this high-frequency domain. SEPIA is installed at the Atacama Pathfinder Experiment telescope (APEX) located at 5100m of altitude at the Chajnantor Plateau at the Atacama desert in Chile.

SEPIA is a heterodyne multi-receiver instrument covering a wide range of submillimeter frequencies including the ALMA Bands 5, 7, and 9 (Belitsky et al. 2018). Among them, the new state-of-the-art SEPIA660 receiver (see Figure 1) has been developed by the NOVA instrumentation group at the Kapteyn Astronomical Institute in Groningen (Baryshev et al. 2015). SEPIA660 is a dual polarization 2SB receiver operating between 578 and 738 GHz (ALMA Band 9) with a broad instantaneous bandwidth of 8 GHz. The development of this SEPIA660 took advantage of the long-standing expertise on the construction of submillimeter detectors in Groningen in close collaboration with the Group for Advance Receiver Development at Chalmers University (Sweden). SEPIA660 was commissioned in 2018 by the NOVA team becoming the first of the second generation of facility instruments at APEX.

Figure 1: SEPIA660 (ALMA Band 9) cartridge, from Baryshev et al. (2015).

At the heart of the Orion Nebula

Located at the middle of the Orion constellation (The Hunter), the Orion Nebula is one of the most popular astronomical objects for both amateur and professional astronomers alike. Visible with the naked eye on the dark sky, the Orion Nebula is located in the middle of the Orion Sword, south from the Belt stars, offering some of the most iconic images in astronomy (see Figure 2). The Orion Nebula is also one of the brightest sources on the sky at submillimeter wavelengths, easily observed from both hemispheres. Not surprisingly, every new submillimeter detector is pointed to the centre of the Orion Nebula for its first light observations, and SEPIA660 was no exception. Early SEPIA660 observations in Orion demonstrate the excellent performance and sensitivity of this new instrument comparable to previous space observations (Montenegro-Montes et al. 2019).

The Orion Nebula is also one of the most studied star clusters in our Galaxy. With more than 2000 stars, the Orion Nebula is the nearest massive cluster in the solar neighbourhood located some 415 parsecs away, and the only one containing high-mass stars (aka Trapezium stars). With most of its stars having formed in the last one million years, the Orion Nebula is a textbook example of a young proto-cluster, partially embedded in its parental cloud. Its proximity makes this cluster an ideal target for high-resolution observations. Key results in the field of star-formation, such as the nature of embedded IR sources (i.e. the BN object), the discovery of proplyds, or the first detection of CO in space among others, have been obtained from the study of this region.

In return of its technical contributions, NOVA was awarded with 35 hours of SEPIA660 guaranteed time observations (GTO) during the ESO observations in 2019, a precious observing time offered to the Dutch community (see first publication byRybak et al. 2020). In the first observations of this GTO time, and as part of a collaboration between the Leiden Observatory and NOVA, we pointed SEPIA660 towards the heart of the Orion Nebula (Hacar et al. 2020). In combination with the excellent observing conditions at Chajnantor, the unprecedented sensitivity of this new SEPIA660 detector allowed us to map, for the first time, the large-scale molecular emission of the so-called OMC-1 region at frequencies around 652 GHz (see Figure 3, lower panel).

Figure 2: The constellation of Orion observed from ALMA at the Chajnantor Plateau (Credits: ESO, https://www.eso.org/public/images/potw1513a/)). The Orion Nebula can be recognized at the center of this image, to the left of the Belt stars.

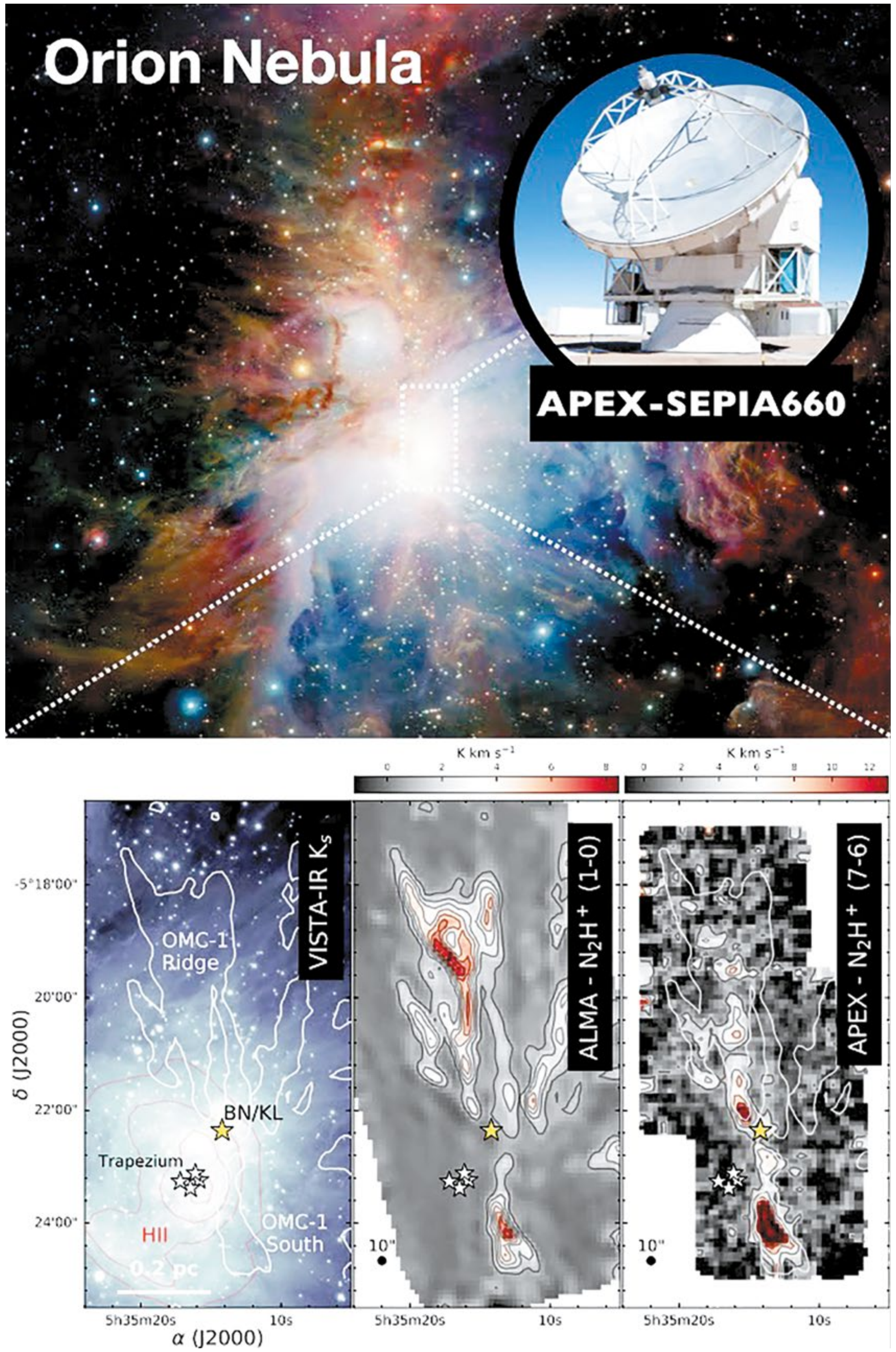


Figure 3: **(Upper panel)** Optical image of the Orion Nebula (credits ESO: https://www.eso.org/public/netherlands/news/eso1625/). **(Lower panel)** New SEPIA660 observations along the OMC-1 region (Hacar et al. 2020).

From left to right: (a) VISTA-IR Ks band, **(b)** ALMA N_2H^+ (J=1-0) (~93 GHz, ALMA Band 3), and **(c)** APEX-SEPIA660 N_2H^+ (J=7-6) (~652 GHz, ALMA Band 9) maps. All molecular maps are convolved into a common Nyquist grid with a final resolution of 10". The intensity of the H41α emission tracing the extension of the ONC HII nebula is indicated in the VISTA image. For reference, the position of the Trapezium (white stars) and the Orion BN source (yellow star), as well as the first contour of the N$_2$H$^+$~(1--0) emission, are displayed in all maps.

Star-formation at extremely high gas densities

As the primary target of our observations, we investigated the emission and distribution of the N_2H^+ molecule across the Orion Nebula. N_2H^+ is a popular tracer of molecular gas at densities of $n(H_2)>105cm^3$. Low rotational transitions of this molecule (J<3-2) are regularly observed at low-frequencies in multiple star-formation studies using radio telescopes such as ALMA (e.g., at Band 3; see Figure 3, lower panel, centre). Our new APEX observations, instead, targeted a much higher transition of this molecule, the N_2H^+ (J=7-6) line (ALMA Band 9). Our SEPIA660 maps in the OMC-1 region show an unexpectedly intense and extended emission of this high-frequency transition along the entire OMC-1 region (Figure 3, lower panel, right).

In addition to its extended nature, the N_2H^+ (J=7-6) spectra show an extremely bright peak emission. With an upper energy of Eu=125 K, this transition can only be excited at extremely high densities. More surprisingly, the emission of this N_2H^+ (J=7-6) becomes brighter than its N_2H^+ (J=1-0) counterpart in multiple positions in our maps. Comparisons with radiative transfer models indicate that these emission properties can only be reproduced if the gas traced by this molecule is at densities of $n(H_2)>107cm^3$. Similar densities have been observed in collapsing dense cores and proto-planetary disks at AU scales. However, this is the first time these extreme densities are reported at parsec scales in clusters.

The Orion Nebula is regularly employed as a local benchmark in most of our current star-formation theories. For the first time, our new SEPIA660 observations demonstrate the existence of large mass reservoirs of star-forming gas at extremely high densities above $n(H_2)>107cm^3$ in these objects. These ultra high gas densities mimic the physical conditions of more distant and massive environments such as Starburst Galaxies or the early Universe. Our new observations reveal this OMC-1 cloud as a unique laboratory to investigate the fragmentation, collapse, and chemical evolution of the gas at these extreme density conditions in young clusters.

Our SEPIA660 early results also highlight the strong benefits of direct synergies between the technical and scientific developments within the Dutch community.

References:

- Baryshev, Hesper, Mena et al. (2015), A&A, 577, A129
- Belitsky, Lapkin, Fredrixon et al. (2018), A&A, 620, C2
- Hacar, Tafalla, Forbrich, et al. (2018), A&A, 610, A77
- Hacar, Hogerheijde, Harsono, et al. submitted to A&A Montenegro-Montes, Torstensson, Parra et al. (2019), The Messenger, 176, 20
- Rybak, Zavala, Hodge, et al. (2020), ApJL, 889, L11

The Curious Case of J1407

Matthew Kenworthy

J1407 is a nearby young star that underwent a complex series of eclipses that lasted for almost two months in 2007. Our best explanation is that an (as yet) unseen massive substellar companion with a giant ring system passed in front of the star, causing the eclipse. We haven't seen another eclipse towards J1407 (or its full name, 1SWASP J140747.93-394542.6), but data from the ALMA telescope array has detected what might be the dust making up the rings themselves.

The discovery

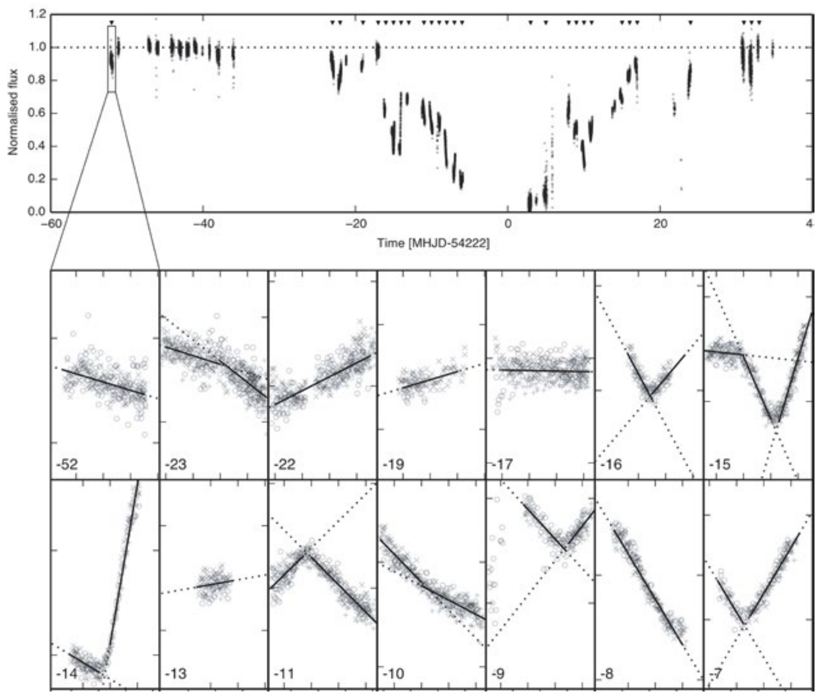


Figure 1: Detailed plot of the J1407 light curve during the eclipse. Top: overview of the light curve. Bottom: nightly light curve for 14 nights during the eclipse, indicated in the upper panel by triangles. The data from three different cameras are plotted with different symbols X O and +.

Mark Pecaut, at that time a graduate student under the supervision of Eric Mamajek at the University of Rochester, discovered the unusual light curve towards the end of 2011, when he was looking at the light curves of young stars as part of his thesis research. Looking through the public light curve database of the SuperWASP collaboration, he found J1407, a star almost the same mass as the Sun, with a light curve that showed a 3% variability that repeated every 3.2 days, almost certainly due to fainter star spots on the surface of the star rotating in and out of view as the star rotated.

J1407 also showed a very long lasting eclipse event from April through May 2007 (see Figure 1; van Werkhoven et al. 2014), where the star's changed brightness on a nightly basis, sometimes as much as 95% of the flux was blocked by something moving in front of the star. The discovery paper (Mamajek et al. 2012) contained a simple model including four large rings about 0.6 au in diameter surrounding an unseen substellar companion, called J1407b, which orbited around the parent star.

Searching for J1407b

Follow up observations were carried out to try and detect J1407b, which must be several tens of Jupiters in mass in order to keep such a large ring system held together and not ripped apart by the gravity of the star. These included looking for another eclipse in other photometric data (no other eclipses were found), looking for the reflex motion of the star as the gravity of the unseen companion tugged on it (the star is young and is very active, preventing the method from being sensitive enough), and directly detecting the thermal glow of the companion itself (no – even with the largest telescopes and sparse aperture masking did not find anything), detailed in Kenworthy et al. (2015).

The best model fit for rings around J1407b are about 200 times larger than Saturn's rings (see Figure 2; Kenworthy and Mamajek 2015), and for the rings a long way away from the planet, the tidal forces of the star J1407 will force them down into the orbital plane of J1407b, some 20 degrees away. The rings should no longer be flat, but have a large systematic warp to them, as calculated by Zanazzi et al. (2017).

Photographs of the night sky have been taken for over a century, and one of the largest collections is at Harvard University. These photographic plates are being scanned in digitally and published onto the internet through the DASCH project. The process is slow and time consuming, especially as you work towards the Galactic plane, where there are far more stars crowded together and disentangling the signals is challenging, but they reached the location in the Galaxy where J1407 is located around 2017. This enabled the baseline for the J1407 lightcurve to be extended back to the 1900's, but still no eclipses were detected. The coverage of the photographic plates from DASCH were combined with others from Sonnenborg and other more recent all sky surveys that looked towards J1407, but still a null result, written up in Mentel et al. (2018).

Meanwhile, the star is being observed every clear night by the dedicated observers of the AAVSO. They watch J1407 for when the next eclipse will start. The constraints they provide rule out successively more orbital periods, leaving J1407b with fewer orbital periods to hide in.

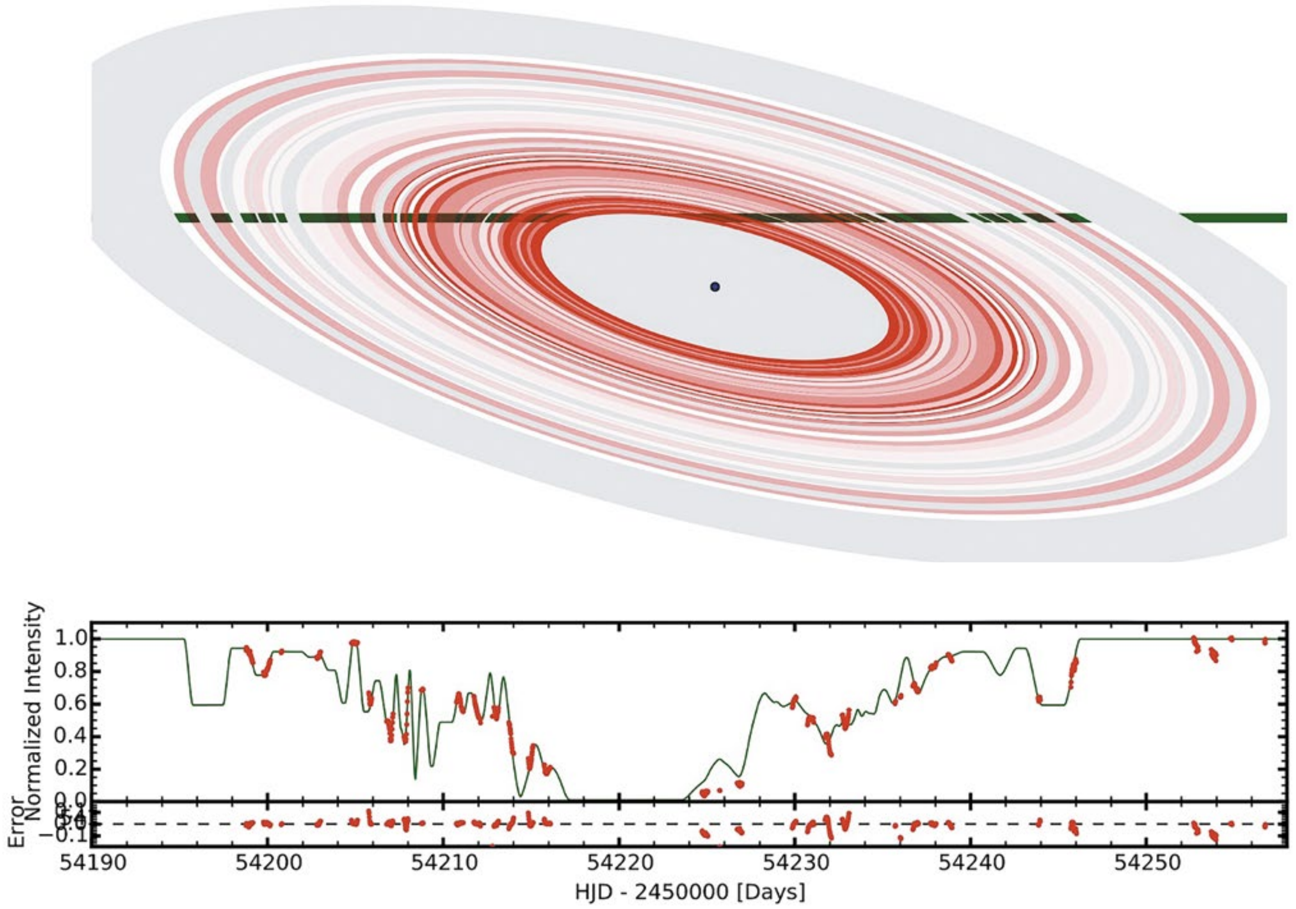


Figure 2: Model ring fit to J1407 data. The image of the ring system around J1407b is shown as a series of nested red rings. The intensity of the color corresponds to the transmission of the ring. The green line shows the path and diameter of the star J1407 behind the ring system. The gray rings denote where no photometric data constrain the model fit. The lower graph shows the model transmitted intensity versus time. The red points are the binned measured flux from J1407 normalized to unity outside the eclipse.

The Glow of the Rings

If the planet J1407b could not be detected, then how about looking for the rings directly?

The rings are probably made of small rock or icy particles, ranging from one micron in size up to rocks and boulders. The surface area of the dust in the rings is vast, so much so that they radiate thermal energy at millimeter wavelengths that can be detected with radio telescopes on the Earth. The most sensitive sub-millimetre telescope is the Atacama Large Millimetre Array (ALMA) in the Atacama desert in Chile. We were able to get observing time on this array of telescopes in the Summer of 2018, and to our surprise we detected a sub-mm source with the brightness we predicted for J1407b's rings (see Figure 3; Kenworthy et al. 2020). At these very long wavelengths, the star J1407 is not visible in ALMA, so we had to calculate the expected location of the star and compare it to the ALMA source. If the source is the same physical object that caused the eclipse in 2007, we run into a big problem – the source cannot be in

a gravitationally bound orbit around J1407.... but there's an unlikely alternative explanation – the object we called J1407b is floating freely through the Galaxy, and just happened to pass in front of a very young star.

To confirm this tantalizing idea, we need another image from the ALMA array. And as of the end of 2019, we have not been able to get the observing time to confirm or deny our latest idea. If this happens to be true, though, then we will never see another eclipse of J1407. But, we hope that J1407b is indeed a bound object, and we hope that one day soon we will see the rings crossing the star.

References:

- Kenworthy, Klaassen, Min et al. (2020), A&A, 633, 115
- Kenworthy and Mamajek (2015), ApJ, 800, 126
- Kenworthy, Lacour, Kraus et al. (2015), MNRAS, 446, 411
- Mamajek, Quillen, Pecaut et al. (2012), AJ, 143, 72
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- van Werkhoven, Kenworthy and Mamajek (2014), MNRAS 441, 2845
- Zanazzi and Dong (2017), MNRAS, 464, 3945

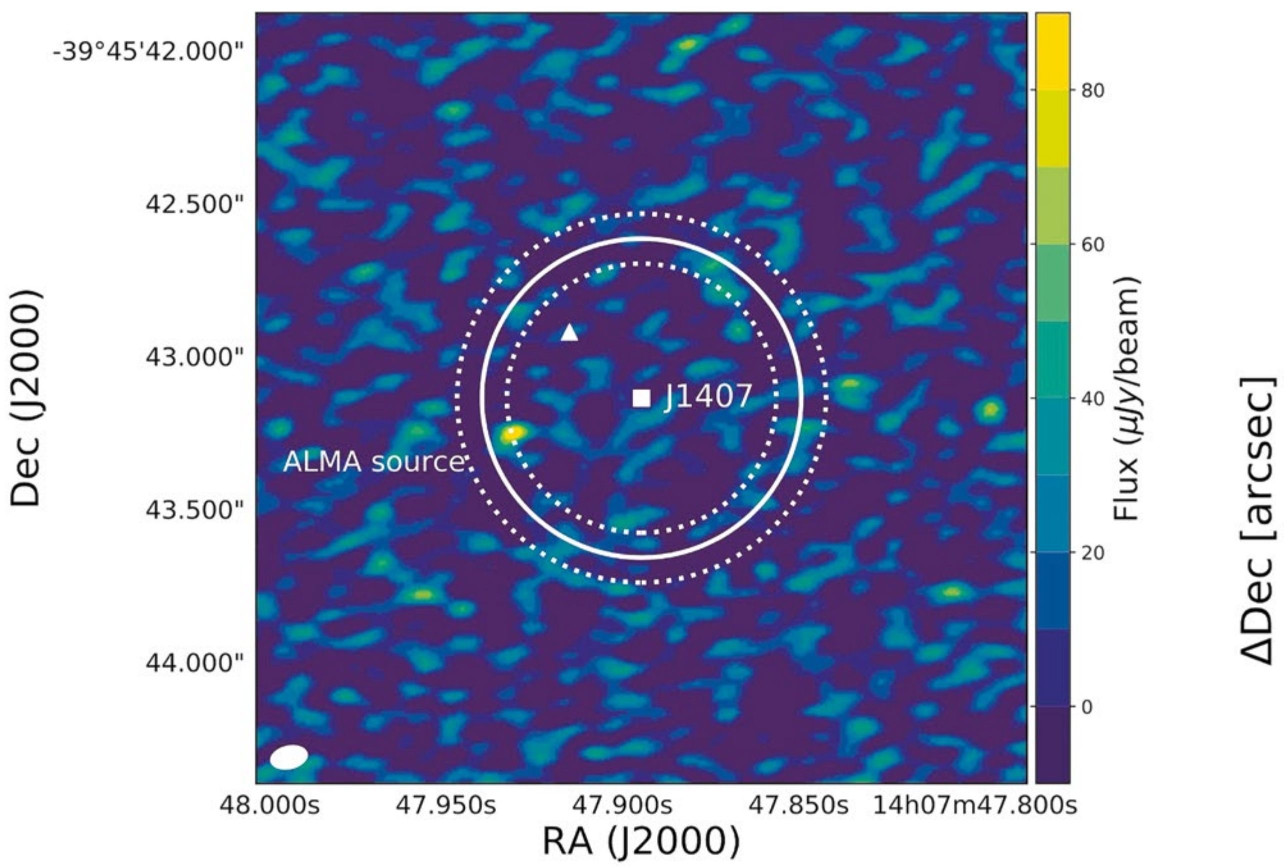


Figure 3: ALMA image of the field towards J1407. The location of the star J1407 in 2017 is shown as a white square, and the white triangle gives the location at the time of the eclipse in 2007. The white ring indicates the expected location for an object travelling at 35 kilometers per second between the two epochs (assuming that the object is co-distant with J1407); the dotted lines represent the 1σ uncertainties. The detected ALMA source is at a position angle of approximately 95 degrees. The ALMA beam is shown in the lower left corner.

PhD Defences

NAME	DATE	SUPERVISOR	THESIS TITLE
G.E. Calistro Rivera	10-01-2019	Röttgering/Hodge	The colours of the extreme Universe – Panchromatic studies of galaxies and accreting black holes
E.G. Bogelund	14-03-2019	van Dishoeck/ Hogerheijde	A Molecular Journey – Tales of sublimating ices from hot cores to comets
P.A. Salas Munoz	30-04-2019	Tielens	A fresh view on carbon radio recombination lines powered by LOFAR
M. Paalvast	18-06-2019	Schaye/Brinchmann	Star formation in dwarf galaxies observed by MUSE
V. Korol	19-06-2019	Tielens/Rossi	Ultra-compact binaries as Astrophysical and Gravitational Wave Sources
V. Kofman	19-06-2019	Linnartz	Laboratory Studies of Water Ice in Space – Optical and Photochemical Properties
A. Saxena	26-06-2019	Röttgering	Forming massive galaxies at the epoch of reionisation
D.N. Hoang	26-06-2019	Röttgering	Cosmic particle acceleration by shocks and turbulence in merging galaxy clusters
X. Bacalla	02-07-2019	Linnartz	Optical Spectroscopy of Interstellar Molecules – Lab oratory Techniques and Observations
M.E. Gasso Miracle	18-09-2019	Van Lunteren	Temminck's Order. Debates on Zoological Classification: I 800 – 1850
V. Vardanyan	18-09-2019	Kuijken	Aspects of Cosmic Acceleration
M.L.R. van 't Hoff	08-10-2019	Van Dishoeck	Chemistry in embedded disks: setting the stage for planet formation
A. Bosman	08-10-2019	Van Dishoeck	Uncovering the ingredients for planet formation
T. Marchetti	10-10-2019	Kuijken/Rossi	Hunting for the fastest stars in the Milky Way
E.F. Retana Montenegro	16-10-2019	Röttgering	Faint Quasars at Very Low-frequencies
E.M. Zari	22-10-2019	De Zeeuw/Brown	Structure and star formation history of the Orion region from earþ Gaia data releases
I. Urdampilleta Aldama	13-11-2019	Kaastra	X-ray spectroscopy of merging galaxy cluster
A. Dvornik	13-11-2019	Kuijken/Hoekstra	The Galaxy-Dark Matter Connection: A KiDS Study
S. Haffert	26-11-2019	Snellen/Keller	High resolution integral-field spectroscopy of exoplanets
A. Mechev	09-12-2019	Röttgering	Orchestration of Distributed LOFAR Workflows
S. van Terwisga	11-12-2019	Van Dishoeck	The Demographics of Protoplanetary Disks: from Lupus to Orion
Ch. Georgiou	12-12-2019	Kuijken	The alignment of galaxies across all scales
P. Cazzoletti	12-12-2019	Van Dishoeck	Not so smooth after all: resolving dust and gas structures in protoplanetary disks

PUBLICATIONS

Publication Overview

Over the year 2019, scientists at Leiden Observatory have contributed to a total of 739 articles in international refereed journals. Astronomy & Astrophysics (193 articles), the Monthly Notices of the Royal Astronomical Society (161 articles), the Astrophysical Journal (98 articles) and the Transient Name Server Discovery Report accounted for 73% of all publications, as reported by the Astrophysics Data System.

COLLOQUIA AND LECTURES

Scientific Colloquia

7 February 2019

Starbursts, outflows, and the emergence of disk galaxies

Christopher Hayward, *Flatiron Institute*

21 February 2019

Follow the chirp: Seeing and listening to the violent Universe with compact object matters

Samaya Nissanke, *University of Amsterdam*

14 March 2019

The Chaotic Origins of LIGO's Binary Black Holes

Nick Stone, *Columbia University*

18 March 2019

Lifting the Veil on Aromatic Chemistry: Complex Carbon Across the Stellar Lifecycle

Brett McGuire, *National Radio Astronomy Observatory*

19 March 2019

The growth and aftermath of supermassive black holes

Ciro Pinto, *ESA*

25 March 2019

Characterising the dense gas in galaxies

Serena Viti, *University College London*

27 March 2019

A Synergy between Solar System and Exoplanets

Yamila Miguel, *Leiden Observatory*

28 March 2019

Tracing the building blocks of life from "star stuff" to terrestrial planets

Melissa McClure, *University of Amsterdam*

1 April 2019

Exoplanet Atmosphere Characterization, Present and Future

Laura Kreidberg, *Harvard-Smithsonian Center for Astrophysics*

3 April 2019

Exploring the Complex Chemistry of Young Solar Systems

Jes Jørgensen, *University of Copenhagen*

8 April 2019

Decoding the Milky Way Galaxy

Ana Bonaca, *Harvard-Smithsonian Center for Astrophysics*

10 April 2019

The Cradle of Planets: From Cosmic Dust to Planetesimals

Paola Pinilla, *University of Arizona*

11 April 2019

First arrival from afar: insight from interstellar planetesimal 1I/'Oumuamua into the past and present of planetary systems

Michele Bannister, *Belfast University*

12 April 2019

SPECIAL COLLOQUIUM: The First Results of the Event Horizon Telescope

Remo Tilanus, *Leiden Observatory & Radboud University*

25 April 2019

The Inclusive University

Marieke van den Brink, *Radboud University*

29 April 2019

Exposing the Physics and Chemistry of large organic molecules in space

Jan Cami, *University of Western Ontario*

2 May 2019

Towards Understanding Black Hole Accretion and Jet Launching

Monika Moscibrodzka, *Radboud University*

6 May 2019

The Molecular Cosmos as seen from the Milky Way

Jens Kauffmann, *MIT Haystack Observatory*

8 May 2019

The photochemical evolution of the interstellar PAH family

Els Peeters, *University of Western Ontario*

9 May 2019

Cosmology with Gravitational Lens Time Delays

Sherry Suyu, *MPA Garching*

16 May 2019

Atmospheric accretion and loss during planet formation

Hilke Schlichting, *UCLA*

23 May 2019

Cassini mission and the seas on Titan

Tetsuya Tokano, *University of Cologne*

6 June 2019

The impact of disk properties on the properties of emerging planetary systems

Christoph Mordasini, *University of Bern*

13 June 2019

Hypervelocity discoveries with Gaia DR2

Douglas Boubert, *University of Oxford*

20 June 2019

The Restless Universe: From PTF to ZTF

Shrinivas Kulkarni, *CalTech*

26 September 2019

Order-Disorder Phase Transition in Black-Hole Star Clusters

Jihad Touma, *American University Beirut*

17 October 2019

Gas dynamics and angular momentum across the Hubble time

Filippo Fraternali, *Kapteyn Institute, University of Groningen*

24 October 2019

Cosmo-chemical, structural, and dynamical clues on the origin of the Solar System

Douglas Lin, *University of California, Santa Cruz*

31 October 2019

Astrophysics meets cosmology: challenges and opportunities

Elisa Chisari, *Utrecht University*

7 November 2019

Hot baryons in the largest cosmic structure

Nabila Aghanim, *Université Paris Sud*

14 November 2019

Massive black holes in the cosmos

Marta Volonteri, *Institut d'Astrophysique de Paris*

28 November 2019

PROMINENT: unraveling the secrets of solar prominences and coronal rain showers

Rony Keppens, *KU Leuven*

5 December 2019

The growth of supermassive black holes in galaxies: a limited merger-AGN connection, red herring bulges, and our parametrized ignorance

Knud Jahnke, *Max-Planck-Institut für Astronomie, Heidelberg*

12 December 2019

The quest for low frequency gravitational waves

Enrico Barausse, *SISSA, Italy*

The Oort Lecture

The Oort Lecture is an annual event, in memory of the famous Dutch 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 general audience with an interest in astronomy. This year's lecture was presented by Prof. Connie Aerts and took place in the Academy Building in Leiden on 17 April 2019.

Prof. Connie Aerts

Conny Aerts graduated as a mathematician from Antwerp University in 1988 and defended her PhD thesis in astrophysics at the University of Leuven in 1993. Through competitive personal grants, she continued her career as postdoctoral fellow of the Research Foundation Flanders from 1993 until 2001, performing numerous stays abroad in Europe, Chile and the USA. She was appointed as Lecturer (2001), as Associate Professor (2004), and as Full professor (2007) at the University of Leuven. Since 2004, she holds the Chair in Asteroseismology at the Radboud University Nijmegen (NL).

Aert's research concerns stellar physics, including stellar structure & evolution and variable stars. She is a pioneer of asteroseismology, which received a major boost thanks to the CoRoT (2006), Kepler (2009), and TESS (2018) space missions. Prior to the era of high-precision space photometry, Aerts developed rigorous mathematical methods to detect and identify non-radial stellar oscillations. Her team designed and applied statistical classification methods based on multivariate Gaussian mixtures and clustering in a machine-learning context, and discovered numerous gravity-mode pulsators in space photometry. As of her appointment as Chair in Asteroseismology at the Radboud University Nijmegen in 2004, Aerts introduced herself into the topic of subdwarf stars, their binarity and pulsations.

In 2008, she was awarded an ERC Advanced Grant to evaluate stellar models from CoRoT and Kepler space asteroseismology. Her PhD students have made major contributions, such as the discovery of non-radial pulsation modes, of dipole mixed modes, and of non-rigid rotation in red giants, following her earlier detections of core overshooting and core rotation in massive stars. This culminated in the 2012 Francqui Prize (widely considered to be the Belgian equivalent of the Nobel Prize), where Aerts was the first woman to receive this prestigious award since its creation in 1933. The ERC offered her a second Advanced Grant to bridge stellar physics and 3D hydrodynamics to remedy shortcomings in stellar evolution theory of massive stars. As a Belgian PI, she is heavily involved in the ESA M3 space mission PLATO.

In her lecture, titled "Starquakes and Exoplanets in our Milky Way", Aerts talked about how recent detections of starquakes by space missions can probe the interiors of stars. While the gas inside stars is beyond reach of classical astronomical observations, starquakes offer a unique way to size, weigh, and age stars with unprecedented precision from a method called asteroseismology. She went on to describe how measurements from the NASA Kepler space telescope reveal the inner rotation of thousands of stars in a much better way than it can be done for the Sun. By combining data from space and ground-based telescopes, the potential habitability of exoplanets can be explored in a most efficient way. Aerts concluded with an optimal roadmap towards the search for life on exoplanets circling a variety of host stars in our Milky Way.

PhD Colloquia

7 January 2019

Faint radio galaxies at the highest redshifts

Aayush Saxena

8 March 2019

A molecular journey – tales of sublimating ices from hot cores to comets

Eva Bøgelund

16 April 2019

A fresh view on carbon radio recombination lines powered by LOFAR

Pedro Salas

4 June 2019

Exploring future multi-messenger Galactic astronomy

Valeriya Korol

12 June 2019

The interplay between stars, gas and dust in faint star-forming galaxies

Mieke Paalvast

14 June 2019

Laboratory studies of water ice-optical and photochemical properties

Vincent Kofman

28 June 2019

Electronic spectroscopy of molecules of astrophysical interest

Xavier Bacalla

10 September 2019

Surveying young stars with Gaia: Orion and the Solar neighbourhood

Eleonora Zari

16 September 2019

Hunting for the fastest stars in the Milky Way

Tommaso Marchetti

17 September 2019

The galaxy–dark matter connection: A KiDS Study

Andrej Dvornik

24 September 2019

High-resolution integral-field spectroscopy of exoplanets

Sebastiaan Haffert

1 October 2019

Uncovering the ingredients for planet formation

Arthur Bosman

7 October 2019

Chemistry in embedded disks: setting the stage for planet formation

Merel van 't Hoff

15 October 2019

X-ray spectroscopy of merging galaxy clusters

Igone Urdampilleta Aldama

22 October 2019

The alignment of galaxies across all scales

Christos Georgiou

10 December 2019

The Demographics of Protoplanetary Disks: from Lupus to Orion

Sierk van Terwisga

11 December 2019

Not so smooth after all: resolving dust and gas structures in protoplanetary disks

Paolo Cazzoletti

17 December 2019

Orchestration of Distributed LOFAR Workflows

Alexandar Mechev

EDUCATION

Bachelor and Master in Astronomy

The 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 typically lasts 3 years and is partly taught in Dutch, with a combination of lectures, problem classes, and practicals. In addition to the 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 Old Observatory building in the center of Leiden, and test their knowledge on coordinate systems during a lecture at the planetarium in Artis, Amsterdam. In the second and third years there is increasing emphasis on astronomy. Highlights include observations at the 2.4m 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 in English, attracting many foreign students. The Observatory has a strongly international flavour, with close ties to other astronomy institutes in Europe and the U.S. Many students, postdocs and staff come from abroad, and the institute hosts 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 laboratory, optics laboratory and high performance computing facilities function as training grounds for students, and are used for student research projects. Students graduate with a broad knowledge of astronomy and astrophysics, but may specialise in various subfields.

In 2019, the MSc programme in Astronomy offered seven specialisations:

1. Astronomy Research
2. Astronomy and Cosmology
3. Astronomy and Instrumentation
4. Astronomy and Data Science
5. Astronomy and Education
6. Astronomy and Business Studies
7. Astronomy and Science Communication and Society

Student Numbers

Student numbers have been continuously rising for several years, and continued to do so in 2019, when 115 freshmen started their studies in the Astronomy BSc. Of this number, 26 (23%) were women, and 46 (40%) pursued a combined astronomy/physics or astronomy/mathematics/computer science degree. The Observatory registered a total number of 265 BSc students at the end of the year, of which 98 aimed at a combined astronomy/physics degree or astronomy/mathematics degree; 35% of all BSc students are female. In 2019, the inflow of master students has stabilised (47 students). In total there were 104 MSc students, including 35 women and 54 of foreign nationality.

Organisation

The entire teaching program is organised and supported by the Education Office of Astronomy (EOA), which deals with all aspects of the curriculum, including organization, student support, outreach and internationalisation. The EAO team currently comprises of the Director of Education, the Head of Education Office Astronomy & Programme Coordinator, a Study Advisor, PR Education Coordinator, Education & Student Affairs Officer and a Support Officer.

In addition to counseling by the student advisor, incoming bachelor students are assigned to small group meetings at regular intervals with a staff mentor and a senior student mentor. In the tutor programme, physics and astronomy freshman students are coached by senior students who volunteer their time for this endeavour. In the Masters programme the buddy system has been continued. In both programmes the students write and submit a Study Plan, which must be approved by the Study Advisor. The astronomy curriculum is monitored by the 'Programme committee' (Opleidingscommissie), which advises the Director of Education on all relevant matters, and which was chaired by Hogerheijde. Under the authority of the Education Committee, the lecture course monitoring system is being continued - students provide feedback to lecturers during and after the course.

Quality control of all aspects of the exams is the responsibility of the Board of Examiners (Examencommissie) chaired by Snellen. Admission to the Masters programme without a BSc in astronomy from a Netherlands university requires a recommendation by the 'Admissions committee' (Toelatingscommissie) chaired by Schrier.

Academic courses and pre-university Programmes

BSc courses

TITLE	LECTURER
Planetenstelsels	Franx
Inleiding Astrofysica	Hoekstra
Praktische Sterrenkunde	Van Langevelde
Modern Astronomical Research & Communication	Russo
Astrobiology	Fridlund
Astronomical Lab & Observing Project	Van Weeren
Keerpunten in de Geschiedenis van de Natuurwetenschappen	Van Lunteren
On Being a Scientist	Van Lunteren/Haring/Smeets
Astronomical Observing Techniques	Rottgering
Galaxies & Cosmology	Hodge
Stars	Snellen
Astronomical Relativity	Rossi
Radiative Processes	Hogerheijde
Bachelor Research Project	Linnartz

MSc courses

TITLE	LECTURER
Astronomical Telescopes and Instruments	Kenworthy/Keller
Computational Astrophysics	Portegies Zwart
Observational Cosmology	Bouwens
Origin and Evolution of the Universe	Schaye
Astronomy from Space	Fridlund
Project management For Scientists	Keller
High Contrast Imaging	Kenworthy
The Aromatic Universe	Tielens
Deep Learning in Astronomy	Portegies Zwart
Numerical Recipes in Astrphysics	Van Daalen
Modern Astrostatistics	Sellentin
Detection of Light	Brandl
Galaxies: structures, dynamics and evolution	Franx
Interstellar Medium	Vd Werf
Large Scale Structure and Galaxy Formation	Kuijken
Science and the public: contemporary and historical perspectives	Van Lunteren
On Being a Scientist	Van Lunteren

Degrees awarded in 2019

A total of 32 students obtained their Bachelor's Degree.

NAME	DATE	PRESENT POSITION
Danker Roozemond	31/01/2019	MSc at Leiden Observatory
Mathijs van Bree	28/02/2019	MSc at Leiden Observatory
Naor Scheinowitz	28/02/2019	MSc Physics, Leiden
David van Dop	28/02/2019	MSc at Leiden Observatory
Pieter Speelman	28/02/2019	MSc at Leiden Observatory
Colin Meulblok	29/03/2019	MSc Physics, Leiden
Ruben Guis	31/05/2019	MSc Physics, Leiden
Jurriaan de Gier	28/06/2019	MSc Physics, Leiden
Joshiwa van Marrewijk	28/06/2019	MSc at Leiden Observatory
Margot Teunisse	28/06/2019	MSc Physics, Leiden
Kasper Roewen	28/06/2019	MSc at Leiden Observatory
Maite Boden	31/07/2019	MSc Physics, Leiden
Merel Donker	31/07/2019	MSc at Leiden Observatory
Stefan van der Giessen	31/07/2019	MSc at Leiden Observatory
Karlijn Kruiswijk	31/07/2019	MSc Physics, Leiden
Brent Maas	31/07/2019	MSc at Leiden Observatory
Aniek van Ogtrop	31/07/2019	MSc at Leiden Observatory
Hendrik van Ommen	31/07/2019	MSc Physics, Leiden
Dani de Boe	31/07/2019	MSc Physics, Leiden
Ernst Traanberg	31/07/2019	MSc at Leiden Observatory
Ivana van Leeuwen	31/07/2019	MSc at Leiden Observatory
Kas Veken	31/07/2019	MSc at Leiden Observatory
Naadiya Jagga	31/07/2019	MSc at Leiden Observatory
Nashanty Brunken	31/07/2019	MSc at Leiden Observatory
Nathan Broughton	31/07/2019	MSc Physics, Leiden
Raphael van Laak	31/07/2019	MSc Physics, Leiden
Silvan Toet	31/07/2019	MSc at Leiden Observatory
Camiel de Valk	31/07/2019	MSc Physics, Leiden
Amber Vervloet	31/07/2019	MSc Physics, Leiden
Yke Rusticus	31/07/2019	MSc Artificial Intelligence at University of Amsterdam
Gerben Jolink	30/08/2019	MSc at Leiden Observatory
David Kleingeld	30/08/2019	MSc at Leiden Observatory

Degrees awarded in 2019

The following 32 students were awarded their Master's degree.

NAME	DATE	PRESENT POSITION
Esmee Stoop	31/01/2019	Data Analyst
Gunjan Bansal	31/01/2019	Job searching
Irene Haasnoot	31/01/2019	Job searching
Michelle Willebrands	28/02/2019	Unawe
Isabel van Vledder	28/02/2019	Rijks I-trainee (Data) bij Rijks ICT Gilde
Lennart van Sluijs	28/02/2019	PhD at Amsterdam
John Hefele	28/02/2019	PhD at Cosine
Erik Weenk	31/07/2019	Job searching
Eva van Weenen	31/07/2019	PhD Applied Data Science at ETH Zürich
Yapeng Zhang	31/07/2019	PhD at Leiden Observatory in Leiden
Tom Sweegers	31/07/2019	Programmer at Time Series
Margot Leemker	31/07/2019	PhD at Leiden Observatory in Leiden
Len Hartsuiker	31/07/2019	Junior Energy trader by Northpool
Vivienne Kolman	26/06/2019	Job searching
Spandan Dash	31/07/2019	PhD at Leiden Observatory in Leiden
Sara Maleubre Molinero	31/07/2019	PhD France
Lennart Prins	31/07/2019	Commodity Risk Analyst bij Eneco
Joost Wardenier	31/07/2019	PhD at University of Oxford, England
Rosalie van Wetten	30/08/2019	Job searching
Vaibhav Vaidya	30/08/2019	Job searching
Yuejia Zhai	31/07/2019	Job searching
Erik Osinga	31/07/2019	PhD at Leiden Observatory in Leiden
Banafsheh Shiralilou	31/07/2019	PhD at University of Amsterdam
Martijn Wilhelm	31/07/2019	PhD at Leiden Observatory in Leiden
Fedde Fagginger Auer	31/07/2019	PhD at Leiden Observatory in Leiden
Brendon Walter	30/08/2019	Data scientist at Incotec
Tania Moraga Calderon	30/08/2019	Lecturer at Greenwich Observatory, London
Jonah Wagenveld	31/07/2019	PhD at MPI for Radio Astronomy, Bonn, Germany
Malavika Vasist	30/08/2019	PhD at University of Liège
Keegan Thompson-Paressant	30/08/2019	Researcher at LESIA
Paul Couzy	30/08/2019	Statistisch onderzoeker bij Centraal Bureau voor de Statistiek
Keith Tirimba	28/11/2019	PhD at University of Florida

PUBLIC ENGAGEMENT WITH ASTRONOMY

Astronomy & Society Projects 2019 Highlights

The aim of Leiden Observatory, and specifically of the Astronomy & Society Group, is to engage the public with the wonders of the Universe and share the scientific, technological, cultural and educational aspects of astronomy with society.

spaceEU

spaceEU is an exciting space outreach and education project which aims to spark the interest of young people in STEAM (Science, Technology, Engineering, Arts and Maths), and to encourage them to consider space-related careers. The project inspires and broadens young minds, develops a sense of European and global citizenship, and through our shared human relationship with space, aims to foster long-term partnerships between people from different countries and cultural backgrounds.

www.space-eu.org

De Oude Sterrewacht Leiden

The Old Observatory features exhibitions that connect astronomy & society. It is also an experimental space for new approaches to inform and engage the public with astronomy and science. In 2019 , Leiden Observatory hosted the IAU100 exhibition, Above Beyond, highlighting 100 years of astronomical discoveries. The exhibition was visited for almost 20 000 people.

www.oudesterrewacht.nl

IAU European Regional Office of Astronomy for Development

This office carries out and coordinates relevant astronomy-for-development activities in Europe, focusing on accomplishing the United Nations Sustainable Development Goals in Europe, but also globally. The E-ROAD works closely with its sister offices around the world to foster development everywhere. All E-ROAD initiatives in Europe will be carried out in cooperation with existing activities of pan-European and national astronomical organisations.

www.astro4dev.eu

IAU astroEDU

IAU astroEDU allows educators to discover, review, distribute, improve and remix science education activities, particularly those with an astronomical, earth or space science focus. It offers a free peer-review service by a professional educator and an astronomer to ensure a high scientific and educational standard.

www.iau.org/astroEDU

Citizen Science Lab

The Citizen Science Lab is an incubator and central hub for citizen science efforts at Leiden University. Through the H2020 project, SciShops.eu, the lab implemented a series of citizen engaging activities with the community in Leiden, leading to the implementation of Plastic Spotter.

www.plasticspotter.nl

Open Science Hub Network

OSHub.Network is currently establishing an European network of 8 community hubs - OSHubs -, that work as mediators in each local community, positioning schools as active agents for collaboration between families, universities, research institutes, industry, enterprises, media, local governments, civil society organizations, and wider society, by engaging in real-life projects that meet societal needs.

https://opensciencehub.net/

Expanding (Event) Horizons

Expanding Event Horizons stimulates the participation of girls and underrepresented minorities in the fields of science, technology, engineering and math (STEM). STEM is increasingly critical for full participation in civic life as well as for employment. In order to achieve this goal a lesson series was designed for primary school children (aged 8-12) on the topic: 'Travel to a Black Hole'.

Space Scoop

Space Scoop brings you the latest astronomy news from across the Universe in a language that's easy to understand. Each Space Scoop begins with a new discovery or image from space. Our partners write a press release that is then shared with us. Four SpaceScoop articles are published each month.

www.spacescoop.org

The International Day of Light

The International Day of Light is a global initiative that provides an annual focal point for the continued appreciation of light and the role it plays in science, culture and art, education, and sustainable development, and in fields as diverse as medicine, communications, and energy. In 2019, IDL activities events in 70 countries were attended by over 1.7 million people.

www.LightDay.org

IAU100

In 2019, the International Astronomical Union (IAU) celebrated its 100th anniversary under the central theme "Uniting our World to Explore the Universe". The IAU100 activities took place at global and regional levels, and especially at the national and local levels and reached around 5 million people. To coordinate the initiative, the IAU has set up the IAU100 Secretariat at Leiden Observatory that prepared a comprehensive programme of Flagship initiatives to reach targeted audiences worldwide through the IAU National Outreach Contact points and National Astronomical Societies.

www.iau.org/iau100

Universe Awareness

The programme aimed to introduce children to the idea of global citizenship at a crucial stage of their development – to show them that they are part of an international community. Until the advent of UNAWE, there were no large-scale attempts to use astronomy as a tool for inspiring and educating young children. UNAWE was active in 63 countries and Leiden University Observatory was the founder and coordinator of the programme.

www.unawe.org

Pre-university programme

The Pre-University programme is aimed at enthusiastic and ambitious high school students from the 5th and 6th grade VWO. 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 March.

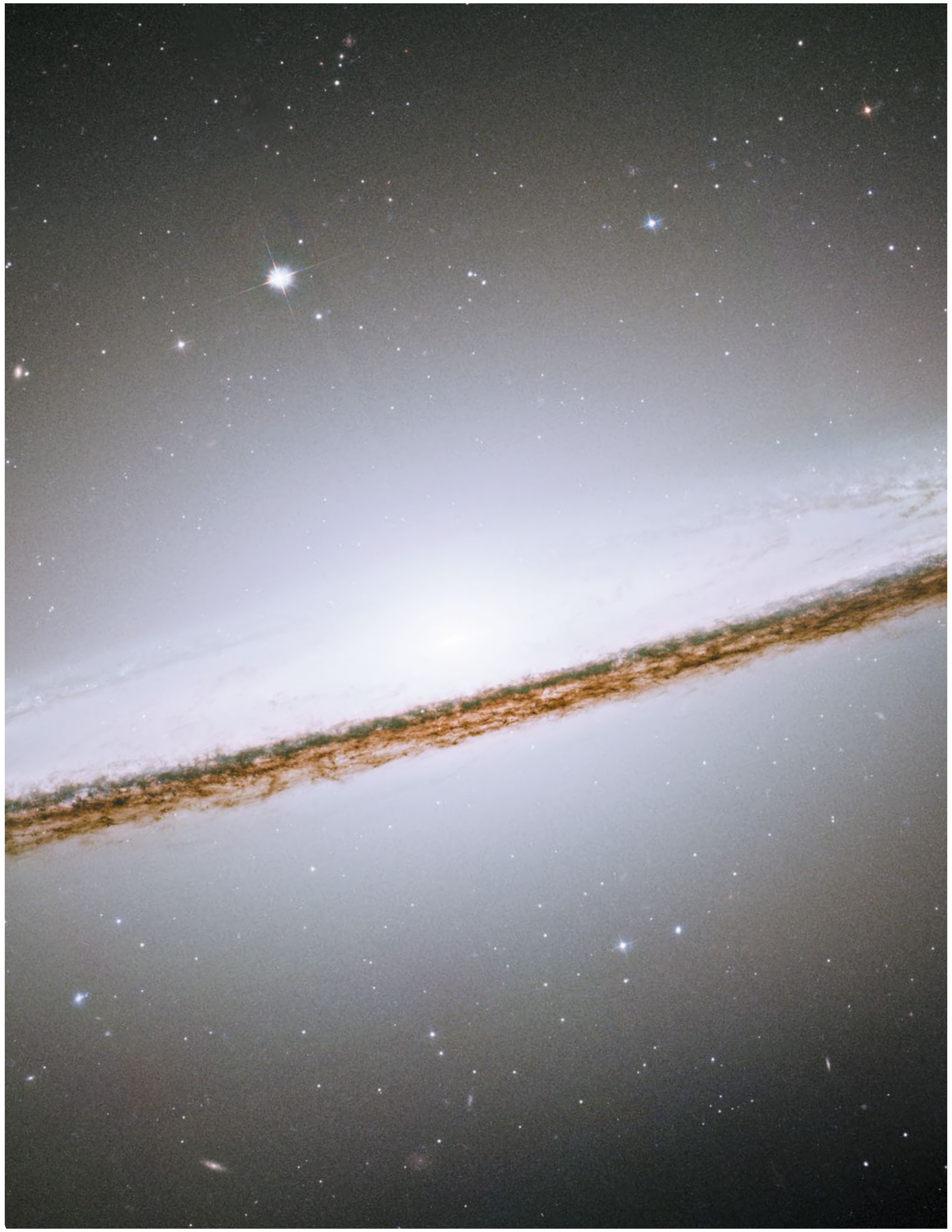
The programme in 2019 consisted of the following meetings:

TITLE	LECTURER
Kosmologie	Hoekstra
Planeten buiten ons zonnestelsel	Snellen
Astrofysica	Icke
Zwarte gaten	Van der Werf
De hemel in 3D	Brown
Bouwen van moleculen en planeten in het heelal	Van Dishoeck
Radiosterrenkunde	Van Weeren

In 2019, there were 18 students from 5 and 6 VWO. They all attended several lectures and went on a field trip to the ASTRON radio telescopes in Westerbork. Each student completed the programme by writing a short article on a subject of their choice. This year, an article on "Black Holes" by Gwen Groeneweg was chosen as the best written article. This article was published in the official PRE-university booklet for 2020. The programme ended with a joint meeting with all participants in the Pieterskerk.

Figure 1: Excursion to the radio telescopes in ASTRON (Netherlands Institute for Radio Astronomy) Dwingeloo – 13 maart 2019.

SOCIAL NETWORKING



LAD F Kaiser

They first called it 'religion', then others started calling it 'time'. Soon seeing the demerit of both these names, a couple of renowned Greeks labeled it as being "math". But, as any good philosopher would say, the numbers were only there to find our raison d'etre. The new concept stuck quite well though: we still highly value mathematics and we also still consider a 'why' question in our science. Yet, these days we dropped its religious value, we call it astronomy and we've come a long, long way since just determining time. But not just in the science itself. Every day, astronomy becomes more and more of a global affair. This makes it important for people to understand what it is and how they can work together. These are exactly the goals L.A.D. 'F. Kaiser' strives to achieve: to connect the people in astronomy and to reach out to the general public.

The Leidsch Astronomisch Dispuut 'Frederik Kaiser' is a student society that was named after the founder of the Old Observatory in the centre of Leiden. This location is also where L.A.D. 'F. Kaiser' has most of its outreach activities. One of the most important things Kaiser does, is training students to give tours at the historic observatory. These tours, together with the visitor centre, help communicate astronomy to the public. In addition, Kaiser is involved in the organisation of major public events at the observatory, such as the annual Nationale Sterrenkijkdagen (National Stargazing Nights), the Museumnacht (Museum Night) and the open day. For these events, Kaiser recruits volunteers and helps plan and execute activities.

Furthermore, the Kaiser Spring Lecture Committee organises the seventh edition of our annual public lecture series this year, de Kaiser Lente Lezingen. The lectures in 2020 are given by Prof. dr. Bernard Foing, Prof. dr. Ignas Snellen, Dr. ir. Annemieke Petrignani and Prof. dr. Huub Röttgering. Their subjects range over various aspects and scales of the Milky Way.

As previously stated however, besides connecting to the public, it is also important to connect as an astronomical community. Kaiser promotes the integration between students and staff by organising social events such as movie nights, excursions, pub quizzes or team activities, like our annual soccer tournament and Lasergame Night. Very popular are the observing nights, where we use the historic telescopes at the Old Observatory to explore the night sky. The evenings are organised by the Kaiser Observing Committee and improved through the collaboration with the WLS (Werkgroep Leidse Sterrewacht), who have a vast knowledge of the operation of the telescopes.

Last but not least, the contact between Kaiser and the VoS (Vereniging oud-Sterrewachters) contributes directly to student's careers. Through this collaboration we create connections between students and alumni, allowing students to better explore what they want to do after their studies and how to achieve these goals.

To make the above activities possible, L.A.D. 'F. Kaiser' has an annual board.

The 2019/2020 board consists of Carmen Turner *(chairman)*, Hannah van Gemert *(secretary)*, Christian Groeneveld *(treasurer)*, Rick Dullaart *(vice-chairman/ assessor Old Observatory)* and Jort Boxelaar *(assessor Old Observatory)*.

The 2018/2019 board consists of Willem Kroese *(chairman)*, Ivana van Leeuwen *(secretary/ assessor Old Observatory)*, Silvan Toet *(assessor Old Observatory)* and Delia Zhang *(assessor Outreach/treasurer)*.

VO-S the Leiden Observatory Alumni Association

The Vereniging van Oud-Sterrewachters ("VO-S") is the Leiden Observatory alumni association. In 2019 several events have been organised.

Studying or working at Leiden Observatory is an unforgettable experience to many. The exciting discoveries of astronomy on one side are complemented with the strong social aspects on the other. Fuelled by the early participation of students in astronomical research and the lively social interaction in this relatively small yet international community, it should come as no surprise that when (under)graduates or staff leave Leiden Observatory to pursue careers elsewhere, good memories often remain of this special period in life. The alumni association VO-S brings our alumni together to keep these ties alive, both on the social level as well as feeding the general interest in scientific astronomical research. As such, it serves as a network between alumni and the institute. Activities comprise of both social and science-related events. The association has about 150 members, with membership open to all Leiden Observatory alumni and staff.

Social activities

On April 17, a number of alumni joined for dinner and drinks at café Barrera, prior to the Oort lecture by prof. Conny Aerts. In the Academy Building, she took the VO-S members on an exciting tour into the world of asteroseismology, showing which undiscovered data we can retrieve from starquakes and how they can tell us more about exoplanets and their habitability.

In June, many VO-S members joined the traditional Observatory barbecue and enjoyed an extensive tour of the new Gorlaeus Building. Remo Tilanus, Scientific Programme Manager of the Event Horizon Telescope, gave an interesting presentation on the first photograph ever of a black hole.

In November the VO-S members met again, at the Kamerlingh Onnes Building, a former building of the Faculty of Science now inhabited by the Faculty of Law. The annual general assembly of members was held therein the Moot Court, a mock-up of a Dutch court room. This meeting was combined with the alumni day of De Leidsche Flesch, the Leiden study association for Physics, Astronomy, Mathematics and Computer Science. This resulted in a lively and inspiring afternoon with two lectures, a boat ride through the city of Leiden and drinks party with live music.

Other activities

We continue to mentor individual students. The sizeable VO-S network serves here as a source of inspiration for those who consider a career outside astronomy.

Communication with the VO-S members on the latest research in astronomy and upcoming activities took place via *www.vo-s.nl*, the newsletter and by e-mail. We thank the Marcom team of the Faculty of Science for their ongoing support in updating the VO-S website and preparing our newsletters.

Join the VO-S!

For contact and membership of our alumni association, visit the VO-S website/ send an email:

www.vo-s.nl
vo-s@strw.leidenuniv.nl.

VO-S Committee:

- Niels van Weeren *(chair)*
- Maaike Damen *(secretary)*
- Gerben Zwart *(treasurer)*
- Anthony Brown *(liaison)*

ORGANISATION

Observatory Staff

FULL PROFESSORS

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

EMERITI

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

AFFILIATE PROFESSORS

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

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

Prof.dr. M. Fridlund
J.H. Oortfonds

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

Prof.dr. C.A. Jackson
ASTRON

Prof.dr. J.S. Kaastra
Senior Scientist SRON

Prof.dr. H.J. van Langevelde
JIVE

ASSOCIATE/ASSISTANT PROFESSORS AND SENIOR RESEARCHERS

Dr. R.J. Bouwens
Dr. A.G.A. Brown
Dr. L. Burtscher
Dr. J.A. Hodge
Dr. M.A. Kenworthy
Dr. P.M. Rodrigues Dos Santos Russo
Dr. E.M. Rossi
Dr.ir. F. Snik
Dr. R. Stuik
Dr. R.P.J. Tilanus
Dr. R.J. van Weeren

TEMPORARY STAFF, POSTDOCS, PROJECT PERSONNEL, LONG TERM VISITING SCIENTISTS

T. Agócs MSc *(guest)*
H. Albanna MSc *(guest)*
Dr. F.J. Alonso Floriano
Dr. Y.M. Bahé *(Marie Curie fellow)*
Dr. J. Bedorf *(guest)*
Dr.ir. M.J.W.A. Begheyn
R. Bergsvik *(guest)*
Dr. M.A. Bilicki
Dr. J. de Boer
Dr. A. Botteon
Dr. J. Bouwman *(assistant professor)*
Dr. M.A. Brentjens *(guest)*
Dr. J. Brinchmann *(guest)*
Dr. X. Cai
Dr. A. Candian *(guest)*
Dr. M. Cautun *(assistant professor)*
Dr. T. Chen *(guest)*
Dr. Y.A. Contreras Morales
Dr. C.A. Correa
Dr. A.J. Cridland
Dr. M.P. van Daalen *(assistant professor)*
Dr. K.J. Duncan
Dr. G. Fedoseev
W. Gao MSc *(guest)*
Dr. C.J. Garcia Vergara
Dr. C. Ginski *(guest)*
Dr. C. Goddi *(guest)*

Dr. M.L.P. Gunawardhana *(Marie Curie fellow)*
Dr. L. Guzman Ramirez
Dr. A. Hacar Gonzalez
Dr. R.H. Hammerschlag *(guest)*
Dr. D.S. Harsono
Dr. J. He
Dr. H.R. Hrodmarsson *(Marie Curie fellow)*
N.P. Hurtado Galleguillos *(guest)*
Dr. S. Ikarashi *(guest)*
Dr.ing. H.T. Intema *(guest)*
Dr. A. Kannawadi Jayaraman
Dr. J.K. Katgert-Merkelijn *(guest)*
Dr. M. Kazandjian
Dr. A.Y. Kesseli
Kofman, dr. V. *(guest)*
Dr. R.D. Köhler *(guest)*
Dr. Z.P. Kostrzewa-Rutkowska
Dr. L. Kreidberg *(guest)*
Dr. J. van Kuilenburg *(guest)*
Dr. A. Kulier *(guest)*
Dr. B.R. Ribeiro
Dr. S.K. Leslie *(Oort Fellow)*
Dr. P. Liebing
Dr. N.F.W. Ligterink *(guest)*
Dr. J.A. Lynn *(guest)*
Prof.dr. S.M. Mao *(guest professor)*
Dr. T. Marchetti

Dr. R.A. Marino *(guest)*
Dr. M.V. Maseda
Dr. M.K. McClure *(assistant professor)*
Dr. J.A. Meisner
Dr. F.D.M. Mernier
Dr. Y. Miguel *(assistant professor)*
Dr. K.L. Miller
Dr. P.D. Mitchell
Dr. P.M. Mollière
Dr. M. Müller
Dr. N.M. Murillo Mejias
Dr. A. Mushtukov
Dr. S. Muzahid
Dr. W.T.T. Nanayakkara
Dr. B.S. Nikiel-Wroczynski
Dr. S. Notsu *(guest)*
Dr. J.B.R. Oonk *(guest)*
Dr. M. Ouellet
Dr. C.H.L. Patty
Dr. P. Paykari *(guest)*
Dr. F.I. Pelupessy
Dr. A.F. Perez Sanchez
Dr. M. Plissi *(guest)*
Dr.S. Plöckinger *(guest)*
Dr. S.M. Pompea *(guest professor)*
Dr. A. Riedo *(Marie Curie fellow)*
Dr. M. Rizzato

G.P. Rosotti
Dr. M. Rybák
C. Salo *(guest)*
Dr. M. Schaller
Dr. R.F. Schulz *(guest)*
A.B. Selie *(guest)*
Dr. E. Sellentin *(Oort Fellow/assistant professor)*
Dr. T.W. Shimwell *(guest)*
Dr. A. Simionescu *(guest)*
Dr. A. Sonnenfeld
Dr. M. Stefanon
Dr. I.M. Stewart
Dr. R. Stuik
Dr. N.J.F. Suas-David
B.X.J.A. Tabone
Dr. S.E. van Terwisga
Dr. M.C. Toribio Perez
Dr. J.W. Trayford
Dr. M. Vakili
Dr. L. Vallini *(Marie Curie fellow)*
Dr. J. Varga
Prof.dr. S. Viti *(guest professor)*
Dr. T.E. Vossen
Dr. T.P.G. Wijnen
Dr. W.L. Williams
Dr. S.G. Wolff *(Oort Fellow)*
Dr. A. Wyttenbach *(guest)*

PROMOVENDI/ PHD STUDENTS

A.S. Abdullah MSc
S.L. Ahad MSc
J. Albert MSc
H.S.B. Algera MSc
Dr. X. Bacalla
A.G. Barr MSc.
R.E. van den Berg MSc
E.G. Bogelund MSc
A.J. Bohn MSc
L.A. Boogaard MSc
S.P. Bos MSc
A.D. Bosman MSc
E.P. Boven MSc
M. Bulak MSc
O. Burggraaff MSc
K.M. Butler MSc
T. Caglar MSc
G.E. Calistro Rivera MSc
D. Campisi MSc
P. Cazzoletti MSc
Y.N. Cendes MSc
E. Chaikin MSc
F.A. Concha Ramirez MSc
O. Contigiani MSc
D.M. van Dam MSc
S.N.B. Debackere MSc
G. Di Gennaro MSc
D.S. Doelman MSc
P. Dorval MSc
G.C. Dufour MSc
A. Dvornik MSc
A.K. van Elteren, ir.
K.L. Emig MSc
F.A.F. Evans MSc
F.J. Fagginger Auer MSc
M.C. Fortuna MSc
M. Frias Castillo MSc
Y. Fu MSc
V. Gamez Rosas MSc
E.M. Gasso Miracle MSc
M.L. van Gelder MSc
C. Georgiou MSc
C.C. Giese MSc
A.J. Gloudemans MSc
M. Gomes Rachid MSc
A.G. de Graaff MSc
Y. Gu MSc
S.Y. Haffert MSc
S. Heikamp MSc
E. van der Helm MSc
M.L.R. van 't Hoff MSc
R.G. van Holstein MSc
D. Klindzic MSc
M.A.M. van Kooten MSc
V. Korol MSc
C.C. Lam MSc

M. Leemker MSc
S. Li MSc
J. Lorenzo Álvarez, ing.
S. Mandal MSc
T. Marchetti MSc
M.N. McCabe MSc
A.P. Mechev MSc
R.I.J. Mostert MSc
P. Nazari MSc
F.S.J. Nobels MSc
M.S.S.L. Oei MSc
E. Osinga MSc
M. Paalvast MSc
C.H.M. Pabst MSc
S. Panchagnula MSc
E.H. Por MSc
D.N. Qasim MSc
L.H. Quiroga Nunez MSc
V.M. Radhakrishnan MSc
S. Reino MSc
E.F. Retana Montenegro MSc
P.A. Salas Munoz MSc
V. Sarkovic MSc
A. Saxena MSc
S.T.M. Schouws MSc
D.B. Serindag MSc
D.M. Smit
L. Stofanová MSc
Y. Sun MSc
F. Sweijen MSc
T. Tax MSc
S.E. van Terwisga MSc
J. Terwisscha van Scheltinga
R. Timmerman MSc
S. Torres Rodriguez MSc
L. Trapman MSc
L. Tychoniec MSc
I. Urdampilleta Aldama MSc
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Member	ESO ELT Project Science Team
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Member	Gaia Science Team
Chair	Gaia Data Processing and Analysis Consortium
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Principal Investigator	Gaia/Netherlands
Member	Gaia Science Team
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Legacy Science Coordinator	Euclid mission
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Coordinator	Galaxy and AGN evolution science working group
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Scientist	MATISSE Project
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Member	MUSE Science team Coordinator
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Member	GATOS collaboration
Theme Lead Agn	METIS science team
Lead	METIS calibration working group
Member	MATISSE commissioning team
Organiser	AGN meeting
Co-Organiser / Head Of "Green Loc"	EAS 2020 meeting

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President	International Astronomical Union
Co-Editor	Annual Reviews of Astronomy and Astrophysics
Member	Raad van de Astronomie
Co-PI	JWST-MIRI European Consortium
Member	NWO Permanente Commissie Grootschalige Wetenschappelijke Infrastructuur
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Member	KNAW
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Member	SKA Extragalactic Spectral line working group
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Member	European ALMA Regional Center Coordinating Committee
Member	European Science Team Origins Space Telescope
Member	German SOFIA Time Allocation Committee
Member	MATISSE Science Group

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Vice-Chair	ESO Observing Program Commitee
Member	Euclid Consortium Coordination Group
Member	Euclid Consortium Editorial Board
Coordinator	Euclid Cosmology Science
Chair	Lorentz Center Astronomy Advisory Board
Coordinator	NOVA network 1
Deputy Coordinator	NOVA NW1
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Member	SOC 2019 Texas Symposium
Member	SOC CosmoGold IAP 2019
Chair	SOC LC Workshop "A century of gravitational lensing"
Member	LISF

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Vice-chair	Editorial Board Mare

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Member	Various IAU scientific committees
Member	VENI selection committee
Scientist	MATISSE Project

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Chair	Athena science working group WHIM
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Member	Editorial board, Astrophysics & Space Science
Member	Hitomi Science Advisory Committee
Member	KRISM Science team
Member	SOC ICAMDATA 2020
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Member	High Contrast Imaging for METIS
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Member	Netherlands Committee for Astronomy
Member	SKA Science working group on radio continuum surveys
Member	NL-SKA contact committee
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PI	LOFAR surveys: Opening up a new window on the Universe

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Member	NL-SKA contact committee
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Member	SKA Science working group on radio continuum surveys
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Core Member	LOFAR Epoch of Reionization science team
Member	Athena X-IFU science team
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Member	EUCLID cosmological simulations working group
Member	Scientific Organizing Committee, Dwingeloo
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Scientific Editor	Scientific Reports
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Reviewer	EU FP7 Network progress
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Member	ALMA-LABOCA ECFS Survey consortium
Member	Herschel Astrophysical Terahertz Large Area Survey consortium
Member	METIS Science Team
Member	STFC Herschel Oversight Committee
Principal Investigator	DESHIMA spectrograph
Principal Investigator	JCMT Cosmology Legacy Survey
Project Scientist	AMKID Submm camera
Organist	Academy Auditorium
Member	Task Force Strenghtening Master Programmes

TIM DE ZEEUW

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Member	ASTRO2020 Steering Committee, National Academy, USA
Member	NWO Adviesraad
Member	KNAW
Member	Stiftungsrat, Heidelberger Institut fuer Theoretische Studien

Grants

P.I.	FUNDER	PROPOSAL TITLE	BUDGET (K€)
Snik	NWO	Compressed spectroscopy & spectropolarimetry for remote sensing of air pollution	926
McClure	NWO	Cometary-Orbit Reservoirs of Volatile Elements for Transport to Terrestrial Exoplanets	250
Callingham	NWO VENI	Radio stars and exoplanets: exploiting a new low-frequency window onto exoplanet habitability	250
Snik	NWO	Development of a robust deployable circular spectro-polarimeter for remote detection of homochirality	11
Snellen	NWO	A first test set-up for flux-collector technology to hunt for biomarker oxygen in exoplanet atmospheres	5
Linnartz	NWO	Butlerov's synthesis in cold dark clouds: formation of sugars during the CO freeze-out stage	5
Hrodmarsson	EU Marie Curie Individual Fellowship	A laboratory study of astronomically relevant large polycyclic aromatic hydrocarbons	176
Van Dishoeck	ESO	NOVA Phase-5 instrumentation program MIRI	189
Russo	EU Open Science Hub Network	Empowering Citizens through STEAM Education with Open Schooling	410
Brown	EU	A Gaia and Herschel Study of the Density Distribution and Evolution of Young Massive Star Clusters	13
Schaye	EU	Big Data applications for Black hole Evolution Studies	257
Viti	EU ERC	Molecules as Probes of the Physics of EXternal galaxies	2462
Schaye	EU	Integrated Activities for the High Energy Astrophysics Domain	24

IN MEMORIAM

Maolin Zhang

He was eager to learn, always seeking to develop his skills, knowledge and experience further. Maolin was friendly, always smiling, modest and grateful for his chances in life. He had many interests outside of astronomy, including table tennis, tennis, Chinese chess, cooking and fishing.

Maolin passed away during the early morning of January 17th 2019 during a terrible fire at his home in Hillegom. We were grief stricken.

Maolin was born on July 25th 1991 and grew up in the countryside near Yangtang Village, Shuangqiao Town, Qidong County, Hunan Province, China. After graduating from secondary school, he was admitted to the prestigious Tsinghua University in Beijing. He obtained a Masters degree in Engineering from the Department of Engineering Physics there in July 2016. His Master's thesis was entitled "Interferometric imaging and data processing". This accomplishment has earned our deepest respect and made him a true hero in his hometown. Over the years his interest in astronomy grew and during the summer of 2014 he participated in a student program at the Netherlands Institute for Radio Astronomy (ASTRON) at Dwingeloo, the Netherlands. Supervised by Tom Oosterloo he used observations taken by the Westerbork radio telescope to learn more about radio astronomy.

Maolin was fascinated by radio astronomy, and so we explored possibilities that might enable Maolin to do a PhD at Leiden. We were both delighted when his application for a scholarship from the Chinese Scholarship Council (CSC) was successful. Maolin travelled to Leiden in mid-2017 and started on a PhD project that involved observations of the distant Universe by the LOFAR radio telescope.

During his first year at Leiden, Maolin's research concentrated on the analysis of LOFAR results on the formation and evolution of massive galaxies and black holes. He reduced data for a sample of radio sources whose properties indicate that they are located at extremely large distances. The results provided an important contribution to a paper that was led by Aayush Saxena, another Leiden PhD student.

Maolin was an extremely intelligent, hardworking and dedicated student with a passion for astronomy.

During his second year, Maolin helped to develop a new Bayesian statistical technique to select large and well defined samples of quasars from a multi-wavelength combination of data from recent surveys from optical telescopes and radio surveys from the LOFAR telescope. Working closely with Ken Duncan, Jonah Wagenveld and me, he was well on his way to publishing his first paper.

The loss of Maolin leaves a deep hole at the heart of our institute. It has been a privilege to know Maolin and to work with him, and it is hard to realise that he is not among us anymore. Maolin's journey to unravel the mysteries of the universe has come to a shocking and unexpected end. We will always remember Maolin as a bright star in our universe.

Prof. dr. Huub J. A. Röttgering
PhD Supervisor

Lo Woltjer

Professor Lodewijk Woltjer passed away on 25 August 2019. Lodewijk Woltjer, known to many as Lo, was born on 26 April 1930 in Noordwijk, the Netherlands, as the son of astronomer Jan Woltjer. He studied at Leiden University, and carried out his doctoral research under Jan Oort. He obtained his cum laude doctorate in 1957, for a PhD thesis on the magnetic field structure of the Crab Nebula.

Following his PhD, Woltjer continued to do research in theoretical astrophysics and plasma physics — studying quasars, supernova remnants and magnetic fields in stars and galaxies. He held postdoctoral research appointments at Yerkes Observatory and at Princeton University, and then returned to Leiden University in 1959 as lecturer of astronomy. He was promoted to professor of theoretical astrophysics and plasma physics two years later, holding the position until 1964.

Between 1964 and 1974 Woltjer worked at Columbia University in New York, first as the Chair of the Astronomy Department and subsequently as Rutherford Professor of Astronomy.

Woltjer returned to Europe at the instigation of Adriaan Blaauw, then ESO's DG, who asked him to set up a science group. He succeeded Blaauw, created the science group, and became ESO's third and longest-serving Director General, from 1975 to 1987. In this period Woltjer oversaw the crucial change from an organization that had achieved its original goal and delivered the 3.6m telescope on La Silla to the multi-programme organization it is today. He decided that the next step should be a facility with four 8m telescopes (rather than 16 4m telescopes, or one 16m telescope), with the possibility of using them together as an interferometer built into this system from the start. He managed to convince the ESO Member States to double their annual contributions to make this Very Large Telescope a reality. He stepped down when he had secured the unanimous approval by the Member States for the VLT project, and the funding had been guaranteed, stating that 'now someone else can build it'. He had already provided strong arguments that Paranal would be an excellent site. This singular achievement was pivotal in ESO's development, and its rise to prominence in world astronomy, and is described in his own book Europe's Quest for the Universe, and, more recently, in Claus Madsen's book "The Jewel on the Mountain Top".

Early in his tenure at ESO, Woltjer selected Garching as the new location of the ESO Headquarters, organized its construction, and oversaw its inauguration in 1981. He convinced Italy and Switzerland to join ESO in 1982. This enabled the construction of the New Technology Telescope, which was a crucial precursor of the Very Large Telescope. He also brought the 15m SEST radio antenna to La Silla. It was the first submillimeter telescope in the southern hemisphere, and paved the way for ESO's further involvement in APEX and in ALMA, both on Chajnantor, a site which Woltjer already visited while he was at ESO. He also strengthened ESO's relationships with other organisations, including signing the agreement with the European Space Agency for the Space Telescope European Coordinating Facility, which was set up at ESO Garching, to enable European astronomers to make optimal use of what would become the Hubble Space Telescope.

Following his time at ESO, Woltjer remained active in astronomy, working at the Observatories at Arcetri and at Haute-Provence. He was the founding President of the European Astronomical Society, serving from 1990-1993, and was President of the International Astronomical Union from 1994 to 1997. He had a key role in the development of ESA's Horizon 2000 plans, working closely with Roger Bonnet, ESA's Director for Science. A decade later, the two of them wrote a thought-provoking book, entitled "Surviving the next 1000 Centuries".

Over the years, Woltjer kept his connections with Chile and ESO, participating in the 50th anniversary gala dinner in Munich in 2012, attending the ALMA inauguration in 2013, visiting the observatories in Chile on several occasions and, as recently as 2017, at the age of 87, attending the First Stone ceremony for the Extremely Large Telescope, and visiting the by now extended Headquarters in Garching for the Reaching New Heights in Astronomy meeting. Lo Woltjer was often accompanied by his wife, Ulla Demierre, who worked with him from the time when he was ESO DG. Ulla preceded him earlier this year, after a short illness. They will both be missed.

Prof. dr. Tim de Zeeuw

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