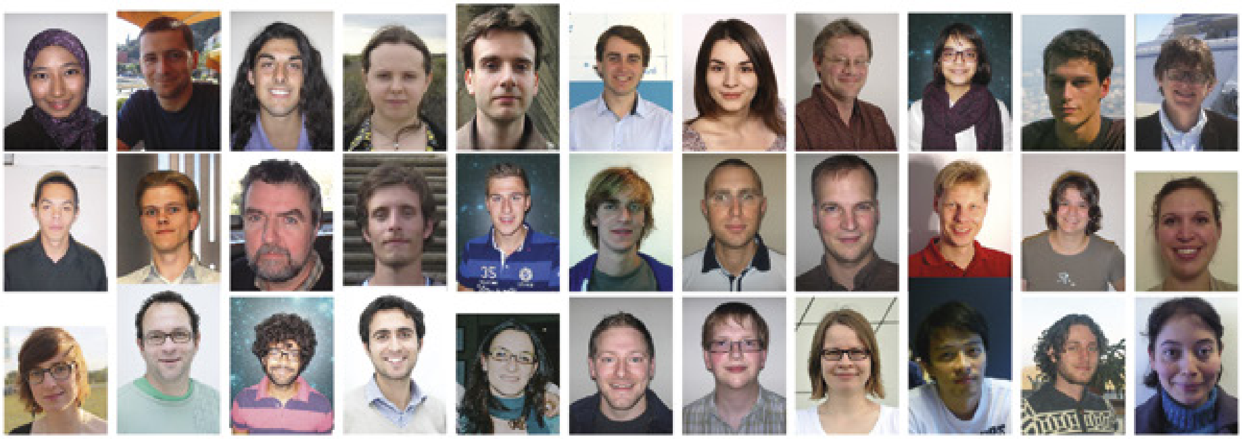

Sterrewacht Leiden

Annual Report 2013

Research Institute Leiden Observatory

(Onderzoekinstituut Sterrewacht Leiden)

Annual Report

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An electronic version of this annual report is available on the web at
http://www.strw.leidenuniv.nl/research/annualreport.php

Production Annual Report 2013:
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Chapter 1

Review of major events

Review of major events

Chapter 1

As a proud member of Leiden Observatory, I am delighted to report that 2013 was again an excellent year for the observatory. Its mission remains to:

- carry out world-class astronomy research, maintain a strong PhD program, help shape future large international observational facilities and develop key technologies for ground breaking astronomical discoveries,
- provide excellent education at the bachelor and master level, not only to prepare students for PhD projects, but also for the general job market, and
- inform the general public of exciting results and the beauty of the Universe.

The research that we carry out covers a broad range and is well matched to the science networks of the national NOVA research school in which the astronomy institutes from Amsterdam, Groningen and Nijmegen partake. Our particular emphasis is on

- observational and theoretical studies of the formation and evolution of galaxies and the structures in which they are embedded
- exo-planets, star and planet formation.

The Sterrewacht has access to first class ground and space-based observational facilities around the world, hosts in-house optical and astrochemical laboratories, and has built dedicated large scale multi-processing computing facilities.

A very important resource are the observational facilities that are provided by the European Southern Observatory (ESO). ESO is a major partner in ALMA, the large mm/submm radio telescope located in the Atacama desert in Chile, officially opened in 2013. Since 2009, Leiden Observatory hosts the Dutch ALMA regional science center ALLEGRO. Funded by NWO, ALLEGRO provides general face-to-face user support for the entire Dutch community. One of its focus points is to help plan and reduce high frequency observations, in particular those using the Dutch-built Band 9 receiver system. Leiden is also the PI institute for METIS, one of the first generation of instruments to be built for the next ESO large telescope project: the Extremely Large Telescope (ELT).

In 2013, there were major achievements related to the three fold mission of the observatory as mentioned above: research, education and outreach. This annual report provides a comprehensive overview of all the activities in these areas. In this preface to the annual report, it is tempting to mention many of the exciting science results that we have produced last year. Instead I would like to refer the interested reader to the first Chapter of this annual report and mention here only a few of the most exciting highlights.

A major and still growing area of research is the study of exo-planets. About ten years ago there was virtually no activity in this field. Now Ignas Snellen, Matt Kenworthy and Christoph Keller spend a significant amount of their time exploring the often surprising properties of exo-planets. Possibly their most fascinating result of 2013 was the first detection of water in the atmosphere of an exo-planet. They studied HD 189733 system that hosts a rather weird exoplanet which orbits its star every 2.2 days and has a temperature of over 1500 degrees Celsius. The team led by Jayne Birkby and Ignas Snellen detected the spectral line of water in this exo-planet atmosphere using the CRyogenic high-resolution InfraRed Echelle Spectrograph (CRIRES) instrument mounted on the VLT. This pioneering study paves the way for future observations with the METIS IR spectrograph on the European Extremely Large Telescope (E-ELT) that will use a similar technique to hunt for potential signs of life, such as oxygen, in the atmospheres of planets similar to the Earth.

Another main area of research is the study of the formation of stars and exo-planets. Many physical processes are involved, including astrochemistry, magneto-hydrodynamics, solid state physics, and radiative transfer processes, to name a few. To address the questions in this field Leiden takes an integrated approach: the combination of observations, theory and laboratory experiments is providing an increasingly better understanding of the forming systems. A fascinating result was obtained by a team of astronomers, among whom are former Leiden PhD Karin Öberg, Michiel Hogerheijde and Ewine van Dishoeck. The team used the Atacama Large mm/submm Array (ALMA) to take the first image of the snow line in an infant planetary system. Its existence and location is important as it is a crucial aspect determining how dusty material coagulates to form planets. On Earth, for example, snow lines occur on mountains, where snowy ski slopes end and the rocky meadows become visible. PhD student Nienke van der Marel also used ALMA to observe for the first time a dust trap in a disk around a young star. These are likely due to dynamical instabilities in disks where so much dust can be collected that comets and planets can form.

Our endowed lectures had (again) very distinguished speakers. This year's Sackler Lecture was presented by David Charbonneau from Harvard University and was entitled "The fast track to finding an inhabited exoplanet". The annual Oort lecture was given by Louis Allamandola from the Space Science & Astrobiology Division of NASA Ames Research Center. The key thread of his presentation was how astrochemists trace the formation and development of chemical complexity in space and how this might provide the primordial seeds for the origin of life on habitable worlds.

In close collaboration with the Leiden University physics and mathematics institutes, the Observatory offers a comprehensive bachelor and master astronomy program. All faculty are involved in BSc and MSc lectures and supervision of research projects. In addition to the normal general astronomy, master students can follow a cosmology track. The emphasis of this track is on understanding the physics of the early universe and how that relates to its overall evolution. During 2013 114 bachelor students and 41 master students followed the broad lecture programme combined with research closely supervised by our staff. Indeed, Leiden observatory is an attractive place to study astronomy.

In 2013 the Leiden/ESA Astrophysics Program for Summer Students (LEAPS) was started. During this program about 20 MSc students from abroad came to the observatory to carry out 10-12 week research projects mostly supervised by postdocs. While the summer students worked really hard (and as a result a number of papers were published - quite an amazing result for such a short period), the group also enjoyed the lively summer atmosphere in Leiden.

Perhaps the most nerve-racking moment was the launch of GAIA. Many people from Europe, including our own Anthony Brown spent a very large fraction of their life during the last 10-15 years in preparation of the launch. And the launch was successful! The extensive press coverage highlighted the enormous scientific promises of this mission. Since the launch the team has been working day and night to commission the satellite and there is now much confidence that the first scientific results will soon be delivered.

Based on polarization techniques that Christoph Keller and his team developed for exo-planet searches the small iSPEX device was conceived. Attached to an iPhone, this device enables to make measurements of small particles in the atmosphere. Winning the Academische jaar prijs 2012 provided funding for a nation wide measuring campaign that took place on July 8, 2013. With more than 5000 measurements, sufficient data was collected to make accurate maps of the fine dust content over Holland. As a result of all these activities, Frans Snik - leader of the ISPEX project - was mentioned in the daily national newspaper "Trouw" as one of the top 100 individuals that contribute significantly to a sustainable environment.

Many small and large workshops were organised by Leiden observatory, often in close collaboration with the Lorentz center. Three large conferences took place. With well over 400 people attending the Euclid mission meeting held at the Stadsgehoorzaal (civic auditorium) in the center of Leiden was a great succes. It focused on updating the consortium members on the scientific goals, mission, payload, and science ground segment. The symposium "Astronomy, Radio Sources and Society. - The Wonderful Century" was held on 10-13 June 2013. The event brought together some of today's top research astronomers, science policy makers, science communicators, and educators and members of the media to discuss several topics on astronomy, radio sources, and society, and to celebrate Professor George Miley's achievements in the different domains of astronomy. Also IAU 297 entitled "The diffuse interstellar bands" was organised. It was dedicated to the long-standing problem associated with the identification of the diffuse interstellar bands.

The students, PhD students, postdocs and staff form the lively heart and soul of the observatory. With 14 PhD defences, 14 young astronomers have shown their ability to significantly contribute to our understanding of the universe. Their period at the observatory has prepared them well for a career either in academia or in industry. We were fortunate to welcome Catherine Walsh on a NWO/VENI project titled "From Molecules to Planets: Exploring the Chemical Heritage of Solar Systems" and Alessandro Patruno on an NWO/VIDI grant to study extreme matter neutron stars and test some specific predictions of Einstein's theory of General Relativity. In 2013, three inaugural lectures were given - an all time high. Paul van der Werf's lecture was titled "The music of the Spheres" and touched upon very interesting parallels between the art of music and scientific endeavours. Ignas Snellen talked about "The Human in the Universe" and sketched in a very entertaining way many of the developments that led up to the field of exo-planet research. Malcolm Fridlund lectured on Space observations of exoplanets - a fascinating story on how advances in space technology and fundamental understanding of science go hand in hand. Huib Jan van Langevelde, director of the "Joint Institute for VLBI in Europe" (JIVE) in Dwingeloo was appointed as professor in Galactic radio-astronomy. Making use of sophisticated radio astronomy techniques he studies young stars and their distribution in the Milky Way.

We are particularly proud of the prizes and honours that our staff have received this year. Marijke Segers won the Lorentz Graduation Prize from the Royal Holland Society of Sciences for her master research project "Weak lensing by GAMA groups from KiDS images". Michael Garrett, director of research institute ASTRON, has received the IBM 2013 Big Data and Analytics Faculty Award for his work in radio astronomy. This annual award aims to enhance scientific research and the co-operation between IBM and top researchers. The Royal Astronomical Society (UK) gave the 2013 Group award to the SAURON team for their outstanding contribution to astronomy. Led by Tim de Zeeuw 14 former members of this project have worked in Leiden, either as a PhD student or as a postdoc. The SAURON project encompassed a detailed spectroscopic study of nearby elliptical galaxies and gave many new insights into their nature. The Pastoor Schmeitsprijs is awarded every 3 years to a young astronomer for very important contribution to astronomy. At the Dutch astronomy conference held in Lommer Belgium (May 15-17) Rychard Bouwens was given this prize for his studies with the Hubble Space Telescope of the most distant galaxies in the Universe. George Miley was honoured with an RAS Honorary Fellowship in recognition of his leadership role in astronomy research.

Finally, I feel very fortunate that the directorship can be (kind of) combined with the life an active scientist. That this is possible is largely due to the excellent atmosphere at the observatory where virtually all people are willing to provide help in the daily running. As result of the collective efforts, Leiden Observatory remains a very special place to study and to carry out research.

Huub Röttgering
Scientific Director.

Chapter 2

Research

Research

Chapter 2

2.1 Solar system

2.1.1 $^{14}N/^{15}N$ detectability in Pluto's atmosphere

Heays and collaborators carried our an exploratory study modelling the observability of N_2 isotopologues in Pluto's atmosphere by the Alice ultraviolet spectrometer aboard the currently enroute New Horizons spacecraft. This is based on current best-guess models of the Plutonian atmosphere and precise spectroscopic data regarding N_2. The nitrogen isotope ratio varies throughout the Solar system and constrains theories of its formation. Measuring this ratio at Pluto would provide another critical datapoint for testing these theories. This simulation is critical for maximising the information obtained by New Horizons mission during its single flyby of Pluto.

2.2 Proto-planetary disks and exoplanets

2.2.1 Direct imaging of extrasolar planets

Kenworthy and Meshkat were involved with two direct imaging exoplanet discoveries this year. One of the stars in the "Holey Disks" Southern sky survey, HD 95086, was found to contain a 5 $M_{\rm Jup}$ extrasolar planet, the lowest mass directly imaged exoplanet. This system promises to be a prime target for the understanding and characterization of extrasolar planets and their atmospheres.

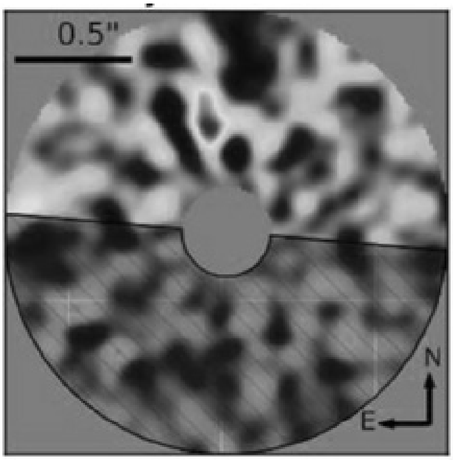

FIGURE 2.1: Image of the extrasolar planet around HD 100546. Its high flux within a disk environment indicates that it is undergoing active accretion (from Quanz et al. 2013).

With Quanz (ETH Zurich), Kenworthy discovered a protoplanet orbiting the star HD 100546 that is showing signs of active ongoing accretion, and with Eric Mamajek from the University of Rochester, the nearby Fomalhaut system was discovered to have a third star associated with it. Kenworthy also carried out the most sensitive search for extrasolar planets at 4 to 10 AU around Fomalhaut, placing lower mass limits of 12 to 20 M_{Jup}.
Kenworthy published a major paper in the analysis of point spread function reconstruction techniques with Codona (Arizona) on Phase Sorting Interferometry. In the paper they show how quasi-static speckles can be modelled and removed, overcoming one of the major limitations of directly imaging extrasolar planets around their parent stars. Kenworthy, in another paper with Codona, Korkiakoski and Keller demonstrated a new and elegant wavefront sensing technique called *differential OTF* which will lead to simple and rapid atmospheric turbulence monitoring.

2.2.2 New type of telescope may detect extraterrestrial life

Snellen, le Poole, Brogi, Birkby and collaborators have shown that with a new type of telescope it may be possible to detect signs of extraterrestrial life on planets orbiting other stars than the Sun. Although even the most nearby stars are at enormous distances, biological activity can reveal itself through gases released in the planet atmospheres, which would otherwise not be present so called biomarker

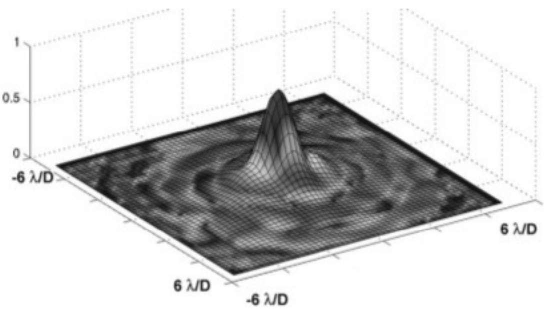

FIGURE 2.2: Image of the complex amplitude of a stellar image recovered using Phase Sorting Interferometry. The alternating rings of red and blue show the recovered zero and pi phases of a classic Airy pattern (from Codona and Kenworthy, 2013).

gases. This idea, which has been around since the 1960s, has now been coupled to a new observing strategy, which uses relatively low-cost ground-based flux collector telescopes for high-precision measurements of oxygen in exoplanet atmospheres.

As has been argued now for several decades, observations of planets orbiting distant stars may one day reveal signs of extraterrestrial life. About one-fifth of the Earth atmosphere consists of molecular oxygen, which is only present because it is generated by biological activity e.g. photosynthesis in plants, and would otherwise be absent because it is so easily spent by oxidation through a range of chemical processes. Finding oxygen in the atmosphere of an Earth-like planet orbiting a distant star could therefore point to extraterrestrial life.

The team has shown that the high-dispersion oxygen signal from a hypothetical Earth-twin planet seen against the light of a red dwarf, a star significantly cooler and five times smaller than our Sun, is only three time weaker than the carbon monoxide signal recently detected in the hot Jupiter tau Bootis. Such red dwarf stars will be hundreds of times fainter than tau Bootis, therefore requiring telescopes significantly larger than currently available. The next generation European Extremely Large Telescope (E-ELT), will be 25 times more powerful than the VLT for this type of measurements, which could make it possible, if lucky, to detect molecular oxygen in a nearby system.

What the team suggests is to invest in the development of flux collector telescopes. For spectroscopy of bright stars and their planets it is not necessary to build a telescope that produces the very sharp images foreseen for the ELT. What is important is to collect as much light as possible, which can be done with a telescope mirror which is less accurately formed and therefore can be constructed for only a small fraction of the cost. With an array of such flux collectors covering a few football fields one could perform a statistical study of extraterrestrial life in the solar neighborhood. Although there is still a long way to go, this should be possible within the next 25 years.

2.2.3 Novel technique boosts hunt for water on exoplanets

Using ESO's Very Large Telescope (VLT), Birbky, Brogi, Schwarz, Snellen, and collaborators have been able to detect the tell-tale spectral fingerprint of water molecules in the atmosphere of a planet in orbit around another star. The discovery endorses a new technique that will let astronomers efficiently search for water on hundreds of worlds without the need for space-based telescopes.
In this work the team studied the exoplanet HD 189733b, a world that orbits its star every 2.2 days and is heated to a temperature of over 1500 degrees Celsius. They measured the molecular absorption by tracing the Doppler shift of the water lines in the exoplanet's spectrum as it orbited the star at very high spectral resolution. The fact that the planet is nearly a thousand times fainter than the star makes detecting it very difficult. The team were able to detect the spectral line of water in the exoplanet atmosphere by using the CRyogenic high-resolution InfraRed Echelle Spectrograph (CRIRES) instrument mounted on the VLT.

2.2.4 Studying planet formation with AMUSE

Using the AMUSE environment Portegies Zwart and collaborators examined the formation of planets around binary stars in light of the recently discovered systems Kepler 16, 34 and 35. They conducted hydrodynamical simulations of self-gravitating discs around binary systems. The selected binary and disc parameters were chosen consistent with observed systems. The discs were evolved until they settle in a quasi-equilibrium and the resulting systems were compared with the parameters of Kepler 16, 34 and 35. The team found a close correspondence of the peak density at the inner disc gap and the orbit of the observed planets, and conclude, based on their simulations, that the orbits of the observed Kepler planets are determined by the size of the inner disc gap which for these systems results from the binary driving. This mediates planet formation either through the density enhancement or through planetary trapping at the density gradient inversion in the inner disc. For all three systems the current eccentricity of the planetary

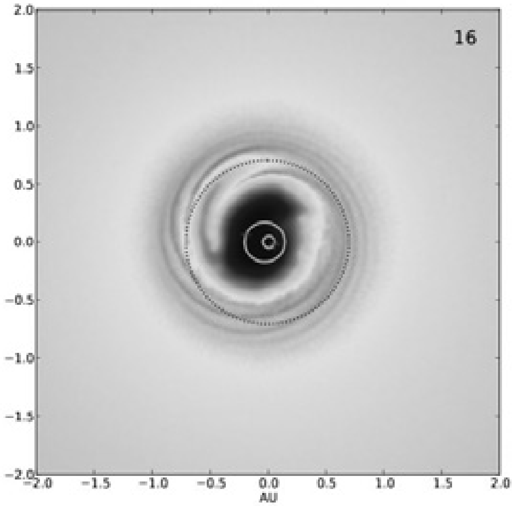

FIGURE 2.3: A slice of the mid-plane gas density of the formation of the planet in orbit around Kepler 16. Also plotted are the orbit of the binary and the approximate orbit of the observed planets (the periapsis angle is matched to the average periapsis angle of the disc material).

orbit is less than the disc eccentricity in the simulations. This, together with the long-term stability of the orbits argues against in situ formation (e.g. a direct collapse scenario of the material in the ring). Conducting additional simulations of systems with a wider range of parameters (taken from a survey of eclipsing binaries), the team found that the planet semimajor axis and binary eccentricity in such a scenario should be tightly correlated providing an observational test of this formation mechanism.

Portegies Zwart and collaborators published the results of the "Cosmogrid" cosmological N-body simulation, which was the first large production simulation to be run across 4 supercomputers on 3 continents using grid technology, as shown in Figure 2.4.

Portegies Zwart and collaborators performed an in-depth study of the post common envelope binary HU Aquarii, which is orbited by two planets. The discovery of two planets in orbit around the CV HU Aquarii (HU Aqr) opens unusual opportunities for understanding the formation and evolution of this system. In particular, the orbital parameters of the planets constrain the past and enabled

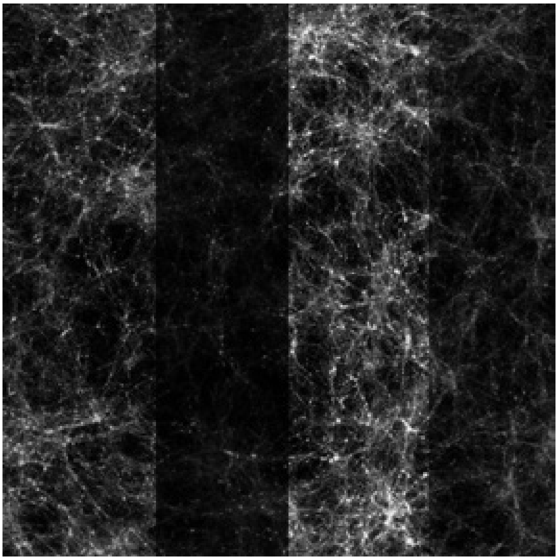

FIGURE 2.4: Snapshot of the "Cosmogrid" cosmological N-body simulation (at z=0) in which the domains of the various supercomputers are colored: red (IB Power6 in Amsterdam, the Netherlands), yellow (Cray XT4 in UK, Edinburgh), blue (Cray XT5 Espoo, Finland) green (Cray XT4 in Tokyo, Japan).

them to reconstruct the evolution of the system through the common-envelope phase. During this dramatic event, the entire hydrogen envelope of the primary star is ejected, passing the two planets on the way. The observed eccentricities and orbital separations of the planets in HU Aqr enabled the team to limit the common-envelope parameter $\alpha\Lambda = 0.45 \pm 0.17$. It is the first time that the common-envelope efficiency has been measured directly from a binary system.

2.2.5 Discovery of a major asymmetric dust trap in a transitional disk

Van der Marel, van Dishoeck, Bruderer (MPE), Birnstiel (CfA), Dullemond and Pinilla (Heidelberg) and collaborators made a big discovery with ALMA early science data: the first observational evidence for a so-called 'dust trap' in the transitional disk Oph IRS 48. The 0.45 mm Band 9 dust continuum revealed an unexpected highly asymmetric distribution rather than a full ring, as was found in the previous mid infrared image of the disk. Such a dust trap had been predicted in models for two decades as a solution for the radial drift problem, which prevents dust to grow beyond millimeter sizes. The 12CO 6-5 data revealed a 20 AU gas

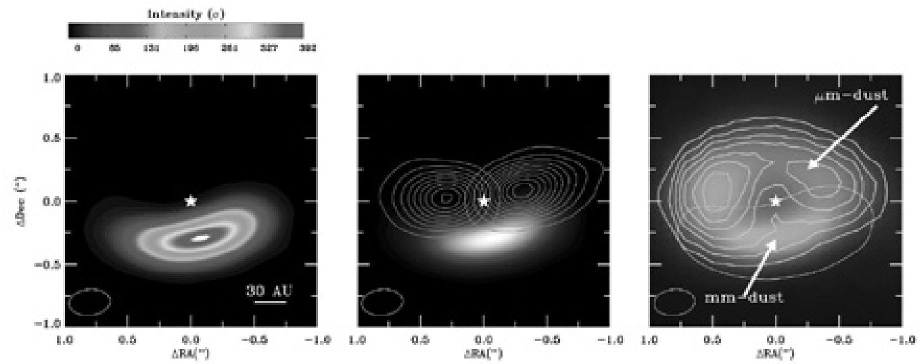

FIGURE 2.5: ALMA Band 9 observations of the IRS 48 transitional disk, revealing a major asymmetric dust trap and a 60 AU radius hole, likely caused by a companion. Left: The 0.44 millimeter (685 GHz) continuum emission. Center: The integrated CO 6-5 emission over the highest velocities in contours showing a symmetric gas disk with Keplerian rotation. Right: The VLT VISIR 18.7 mu m emission in orange contours. The green background shows the 0.44 millimeter continuum (from: van der Marel et al., Science).

hole, likely caused by the presence of a substellar companion or planet. At the edge of such a hole a vortex can be formed, which can trap the millimeter dust efficiently and cause these extreme asymmetries. The discovery was published in Science and presented in several conferences regarding disks and attracted significant international press coverage.

2.2.6 Tracing the CO snowline in disks with N2H$^+$ and DCO$^+$

In 2013 the newly constructed ALMA observatory started to produce science results in earnest. Allegro, the ALMA Regional Center node in the Netherlands, is hosted by Leiden Observatory, and provided assistance in several of the ALMA science results that where published this year. Staff members of Allegro, in collaboration with other scientists at Leiden Observatory and elsewhere, also used public ALMA Science Verification data in their own research into protoplanetary disks. Two teams, led by Klaassen and Mathews, and including Hogerheijde, van Dishoeck, Juhasz, Mottram, Harsono, and Schmalzl focused on the disk around the young Ae star HD 163296.

The disk around this 2.3 solar-mass star was observed with ALMA during Science Verification in a number of molecules including CO and HCO$^+$. two of the more

abundant molecules observable in a protostellar disk. Using this data, Klaassen et al. were able to find the first evidence for a disk wind coming from a protostar, and Mathews et al. made the first image of the CO snow line in this type of system.
A disk wind (like that seen by Klaassen et al.) is a means of releasing the build up of angular momentum that occurs as a forming star accretes material from it surrounding disk. This type of wind, launched from a few AU from the star, was predicted in the 1980s, but had as yet not ever been imaged. These ALMA observations not only detected the emission from this disk wind, but were able to show that the wind has a characteristic double helix/corkscrew morphology which suggests that the wind is magnetically collimated.
A snow line is the distance from a star at which a specific molecule (CO, H2O, etc) freezes out of the base phase because the local temperature is below its sublimation point. Molecules such as CO have much lower freeze out temperatures than water, and so the CO snow line is much further from the star, and thus easier to detect. Using the morphology of the DCO^+. two of the more abundant molecules observable in a protostellar disk. Using this data, Klaassen et al. were able to find the first evidence for a disk wind coming from a protostar, and Mathews et al. made the first image of the CO snow line in this type of system.
A disk wind (like that seen by Klaassen et al.) is a means of releasing the build up of angular momentum that occurs as a forming star accretes material from it surrounding disk. This type of wind, launched from a few AU from the star, was predicted in the 1980s, but had as yet not ever been imaged. These ALMA observations not only detected the emission from this disk wind, but were able to show that the wind has a characteristic double helix/corkscrew morphology which suggests that the wind is magnetically collimated.
A snow line is the distance from a star at which a specific molecule (CO, H2O, etc) freezes out of the base phase because the local temperature is below its sublimation point. Molecules such as CO have much lower freeze out temperatures than things like water, and so the CO snow line is much further from the star, and thus easier to detect. Using the morphology of the DCO^+ emission (DCO^+ is the deuterated version of HCO^+), Mathews et al. inferred the location of the CO snow line in this disk. DCO^+ is most abundant at temperatures near the freeze out temperature of CO, and indeed, when comparing the DCO^+ morphology to the expected temperatures in the HD 163296 disk, the DCO^+ is most abundant at the CO snow line.
Another way to infer the location of the snow line was illustrated by Qi and Öberg (both Harvard) in collaboration with Hogerheijde and van Dishoeck. Using the

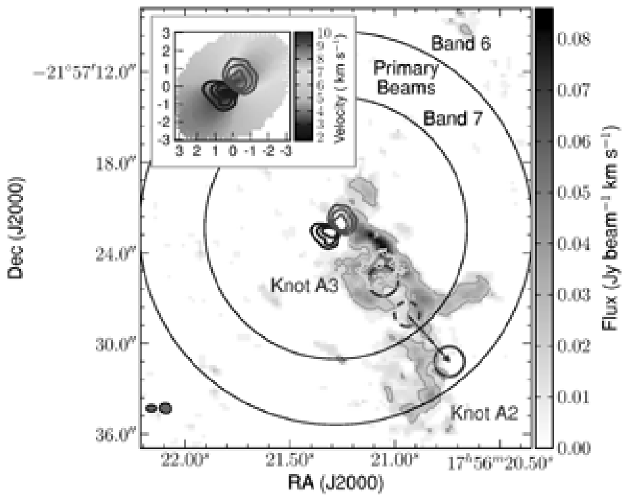

FIGURE 2.6: Blue-shifted molecular disk wind from HD 163296 reported by Klaassen et al. (2013) using ALMA Science Verification data. Nodes in the blue-shifted CO emission coincide with the location of Herbig-Haro knots, taking into account their proper motion.

N2H$^+$ molecule, they find with ALMA the location of the CO snow line in the disk around TW Hya. N2H$^+$ is only present outside the CO snow line, since gas-phase CO rapidly reacts with N2H$^+$, destroying this species.

2.2.7 Far-infrared line survey of disks

Fedele and Bruderer (MPE), together with van Dishoeck, Evans (Texas) and the DIGIT team analysed far-infrared (50-200 μm) spectroscopic observations of young pre-main-sequence stars taken with Herschel/PACS. The sample includes 20 Herbig AeBe and 8 T Tauri disks. Multiple atomic fine structure and molecular lines are detected: [O I], [C II], CO, OH, H_2O, CH^+. The most common feature is the [O I] 63 μm line detected in almost all of the sources, followed by OH. The OH emission is found to come from a warm (few hundred K), dense layer in the disk at intermediate stellar distances. Herbig AeBe sources have higher OH/H_2O abundance ratios across the disk than do T Tauri disks, from near- to far-infrared wavelengths.

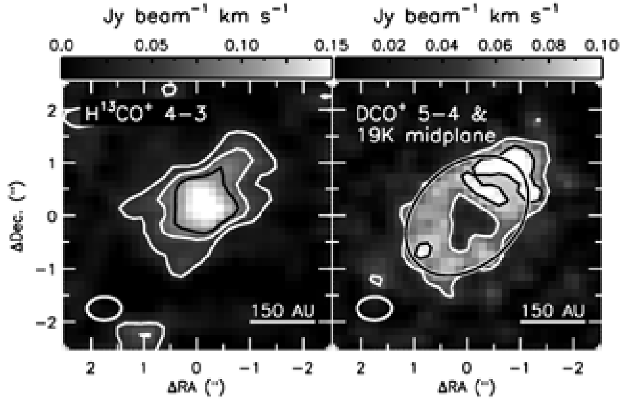

FIGURE 2.7: HCO^+ emission (here seen in its $H13CO^+$ isotopologue, left) fills the disk around HD 163296, seen in ALMA Science Verification data. In contrast, the deuterated version, DCO^+ (right), only exists in a narrow ring around the CO snow line, as predicted by chemical considerations (from Mathews et al. 2013)

2.3 Protostars

2.3.1 Water in star-forming regions with Herschel (WISH)

WISH is a Herschel large program designed to probe the physical and chemical structures of young stellar objects using water and related molecules and to follow the water abundance from collapsing clouds to planet-forming disks (PI: van Dishoeck). It involves a collaboration across the world and includes Mottram, Yildiz, San Jose Garcia and Harsono. A major review on the water chemistry by Van Dishoeck was published in Chemical Reviews summarizing many Herschel highlights.
Water is proving to be an excellent tracer of the kinematics of clouds, including infall from cores to envelope scales. While theories of how this takes place have been around for some time, the velocity profile around protostars is poorly constrained. Mottram, together with the WISH team, has modelled water lines of 7 protostars observed with Herschel-HIFI that show infall signatures in water line observations using non-LTE radiative transfer models coupled with a simple chemistry. For the well-studied Class 0 protostar NGC 1333-IRAS4A the data probe

infall over the whole envelope to which our observations are sensitive (r>1000 AU). For four other sources infall takes place on core to envelope scales (i.e. 10000-3000 AU). The mass infall rate in NGC 1333-IRAS4A is large (10^{-4} M_{Sun} yr^{-1}), higher than the mass outflow rate and expected mass accretion rates onto the star. This suggests that any flattened disk-like structure on small scales will be gravitationally unstable, potentially leading to rotational fragmentation and/or episodic accretion.

Kristensen (Harvard), together with van Dishoeck and the WISH team, found a new, distinct velocity component in HIFI spectra of H_2O towards low-mass protostars not seen in observations from the ground of CO or other species. The component is also seen in high-J CO, OH^+, CH^+, C^+, and OH lines. Inferred excitation conditions imply that the emission arises in dense (10^6-10^8 cm^{-3}) and hot (T $\sim$ 750 K) gas. The H_2O and CO column densities imply a low H_2O abundance of $\sim 10^{-2}$ with respect to CO. This component likely arises in dissociative shocks close (within 100 AU) to the protostar, an interpretation corroborated by a comparison with models of such shocks.

San Jose-Garcia, Mottram and the WISH team explored the similarities and differences between low- and high-mass young protostars from both the physical and chemical perspective by analysing high-J (up to J=10-9) HIFI CO spectra. A strong linear correlation between the logarithms of the CO and isotopologue line luminosity and bolometric luminosity is found across six orders of magnitude on both axes. This suggests that high-J CO lines primarily trace the amount of dense gas associated with protostars. The relation can be extended to larger (extragalactic) scales. In addition, a broadening of the line profile is detected from pre-stellar cores to embedded protostars, which is due mostly to non-thermal motions (turbulence/infall). These results indicate that the physical processes revealed by CO in protostellar envelopes have similar characteristics across the studied luminosity range.

2.3.2 Where has all the O_2 gone in low-mass protostars?

According to traditional gas-phase chemical models, molecular oxygen, O_2, should be abundant in molecular clouds, but until recently, attempts to detect interstellar O_2 line emission with ground- and space-based observatories have failed. Yildiz, van Dishoeck, Acharyya (Kolkata), Goldsmith (JPL) and collaborators used Herschel-HIFI to search for O_2 at 487 GHz toward a deeply embedded low-mass protostar. No feature was detected at the envelope velocity, implying one of the lowest abundance upper limits of O_2/H_2 ever, $<6\text{x}10^{-9}$ (3 sigma). The O_2/CO abundance ratio is less than 0.005. To reproduce these low limits, gas-grain chemical models require a long pre-collapse phase ($\sim 10^6$ years), during which atomic and molecular oxygen are frozen out onto dust grains and fully converted to H_2O, consistent with laboratory experiments carried out in the Sackler laboratory. The low O_2 abundance in the collapsing envelope suggests that the gas and ice entering protoplanetary disks is very poor in O_2.

2.3.3 Modeling disk formation

Theoretical model of star formation predict an evolving physical and kinematical structure as the star and its accretion disk forms. With the availability of high-quality spectrally resolved CO rotational molecular lines observed with Herschel and ALMA, it is timely to simulate the predicted CO lines evolution and quantify the disk's contribution to such lines. Harsono, in collaboration with Visser (Michigan), Bruderer (MPE), van Dishoeck, Hogerheijde and Kristensen (Harvard) simulated the time dependent CO rotational and ro-vibrational lines from two-dimensional physical and chemical structures. The derived CO excitation temperatures from submm rotational transitions do not evolve with time, in contrast with their SEDs. Rotational transitions of CO observed within single-dish beams do not contain a significant fraction of disk emission.

2.3.4 Detection of the youngest rotationally supported disk with ALMA

Rotationally supported disks are critical in the star formation process. The questions of when they form and what factors influence or hinder their formation have been studied but are largely unanswered. Murillo (MPE/Leiden), in collaboration with Lai (Taiwan), Bruderer (MPE) and van Dishoeck observed VLA1623 with ALMA. This is a triple non-coeval protostellar system, with a weak magnetic field perpendicular to the outflow, whose Class 0 component, VLA1623A, shows a disk-like structure in continuum. The PV diagrams of the $C^{18}O$ 2-1 line emission suggest the presence of a rotationally supported component with a radius of at least 50 AU. Kinematical modeling of the line emission shows that the disk out to 150 AU has Keplerian rotation. The central source mass is only ~ 0.2 M_{Sun}. VLA1623A is the youngest source to date for which a rotationally supported disk has been found.

2.3.5 Probing high-mass star-formation with masers

Van Langevelde together with Vlemmings (Onsala) and Surcis (JIVE) used methanol masers to study the relation between outflow and magnetic fields in high mass star forming regions. Progress was made with a statistically significant sample of sources with known outflows and magnetic fields measured through the Zeeman effect. The first results show a correlation between the magnetic field orientation and the direction of early outflows. However, some of the interpretation depends on the methanol Lande factors, for which no accurate values are known. A collaboration started with the EMFL and Chemistry experts in Nijmegen to measure this in the laboratory and make progress with theoretical calculations.
Van Langevelde was involved in various maser astrometry programmes that aim to measure the kinematics of the Galaxy, through methanol or SiO maser parallax observations. Preparations were made to start a large-scale programme on the VLBA. In addition some effort was made to explore measuring the inner Galaxy masers with VLBI telescopes under construction in Africa.

2.4 Stars and compact objects

2.4.1 GAIA

The Gaia group in Leiden, led by Brown, participates in the preparatory and operational phases of the data processing for ESA's Gaia mission. Launched in December 2013, Gaia aims at providing a stereoscopic census of the Milky Way by measuring highly accurate astrometry (positions, parallaxes and proper motions), photometry and radial velocities for 1 billion stars and other objects to 20th magnitude. The main activities in 2013 were:
1) Van Elteren and Brown worked on the development of the data processing software for the photometric instrument of Gaia in collaboration with groups in Rome, Teramo, Cambridge, and Barcelona. The photometric data for Gaia will be collected through low dispersion spectrophotometry with prisms and the group in Leiden is responsible for developing the algorithms that extract the spectra from the raw data. Van Elteren worked to make the photometric processing modules in the Gaia Initial Data Treatment pipeline ready for the commissioning phase of the mission in early 2014.

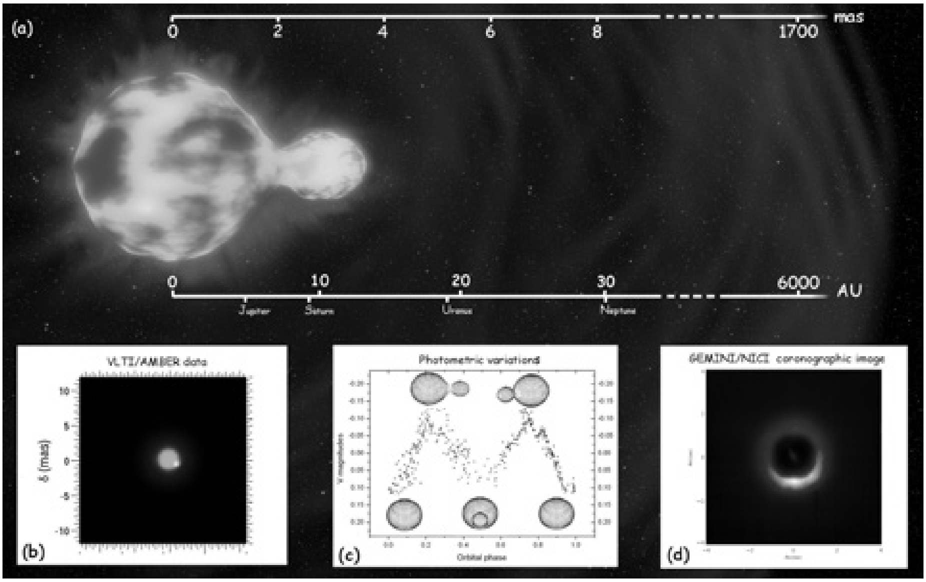

FIGURE 2.8: Artist's impression of the hyper giant HR5171, with the Amber data, photometric variations, and Gemini/NICI data superimposed (credit - Olivier Chesneau/ESO/VLT/GEMINI/NICI).

2) In his capacity as Chair of the Gaia Data Processing and Analysis Consortium (DPAC) Executive Brown worked on numerous aspects of coordinating the consortium in reaching its goals of being ready to process Gaia data after launch. In particular Brown coordinated the planning of the DPAC activities during the commissioning phase of Gaia. He updated the DPAC publication and data access policies, and drafted a publication plan. As a member of the Gaia Science Team Brown led a white paper on astrometry mission options for ESA's L2/L3 mission slots.

2.4.2 The fast evolution of the variable yellow hypergiant HR5171A

An international team led by Chesneau (Observatoire de la Cote d'Azur, Nice, France), consisting of 23 astronomers, among which Van Genderen, analyzed and discussed AMBER/VLT Interferometric observations made in 2012 (ESO, Chile), and 60 years of archival photometric data (JHKL, UBV, VBLUW, uvby and amateur visual photometry) of the variable yellow hypergiant HR5171A = V766 Cen.

This unique program for a massive star in a crucial stage of its life, was initiated by Chesneau and his collaborators Meilland, Chapellier and Millour (Nice). One of the peculiarities of the object was the apparent fast evolution to the red in the HR diagram based on an earlier photometric analyses by Van Genderen in 1992.
The AMBER/VLTI observations revealed a surprisingly large diameter, implying a radius roughly of the size of Jupiter's orbit, making the star one of the largest known. Additionally, a close companion star, but much smaller and fainter, but slightly hotter, was discovered. Indeed, the analysis of the most stable parts of the archival light curve (after 1980), revealed a light curve indicative of an tidally distorted double star, with an orbital period of 3.6 yr. The current mass is 40 M_{Sun}. The binary is imbedded in an huge IR radiating envelope, due to a high mass-loss rate over the last 300-1000 yr.
An analysis of the B and V light curves made between 1960 and 1980, revealed that the brightness in B declined much faster than in V, implying a surprisingly fast decline of the temperature by a few hundred degrees. Thus, pointing to a fast increase of the radius of the primary within its Roche lobe. Never before, such a short lasting and crucial stage of massive star evolution has been observed.
This process reinforced the common envelope phase of the contact binary with mass transfer. Additionally, the loosely bound envelope of the primary with a very low gravity (log g ∼0) will be subject to a stripping off process by the companion. The expectation is that the primary will become a Wolf-Rayet star ending its life with a SN explosion.

2.4.3 Surprising detection of an equatorial dust lane on the AGB star IRC+10216

Low to intermediate mass stars evolve into large, luminous and cool giants at the end of their lives. Their sudden death is caused by intense mass-loss removing the stars outer envelope and the fuel required for nuclear burning, leading to the formation of a planetary nebula. In contrast to the highly asymmetrical shapes of planetary nebulae, the circumstellar environments of their immediate progenitor stars on the asymptotic giant branch (AGB) appear to be spherically symmetric. Explaining how and when planetary nebulae are shaped remains elusive because of the difficulty in directly imaging the morphology of the preceding high mass-loss phase, as these stars are heavily enshrouded in an optically thick dusty envelope. To understand the morphology of the circumstellar environments of AGB stars Keller and his team observed the closest carbon-rich AGB star IRC+10216 in

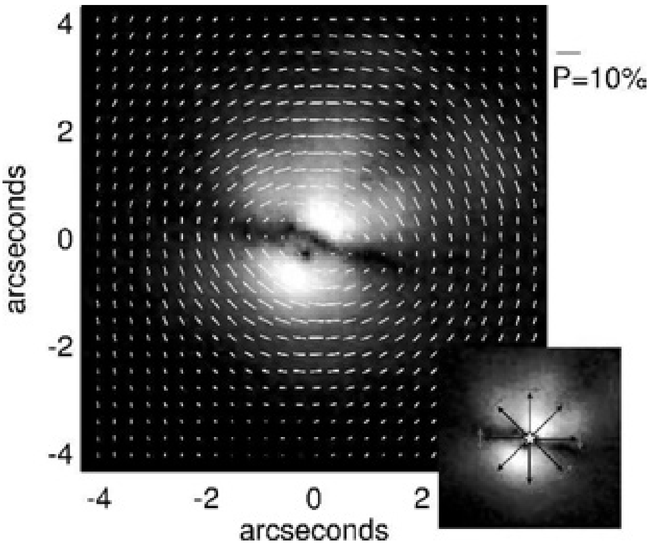

FIGURE 2.9: ExPo image of the circumstellar environment of IRC+10216 in polarised intensity observed at optical wavelengths 500-900nm. The intensity scale is logarithmic and the length of the vectors represents a lower limit to the true polarization degree. North is up and east is to the left.

scattered light with their ExPo instrument at the William Herschel Telescope. When imaged in scattered light at optical wavelengths, IRC+10216 surprisingly shows a narrow equatorial density enhancement, in contrast to the large-scale spherical rings that have been imaged much further out. Radiative transfer models are used to interpret this structure in terms of two models: first, an equatorial density enhancement, commonly observed in the more evolved post-AGB stars, and second, in terms of a dust ring model, where a local enhancement of mass-loss creates a spiral ring as the star rotates. It is concluded that both models can be used to reproduce the dark lane in the scattered light images which is caused by an equatorially density enhancement formed by dense dust and not a bipolar outflow as previously thought. No constraints on the formation of the equatorial density enhancement by a binary system can be placed.

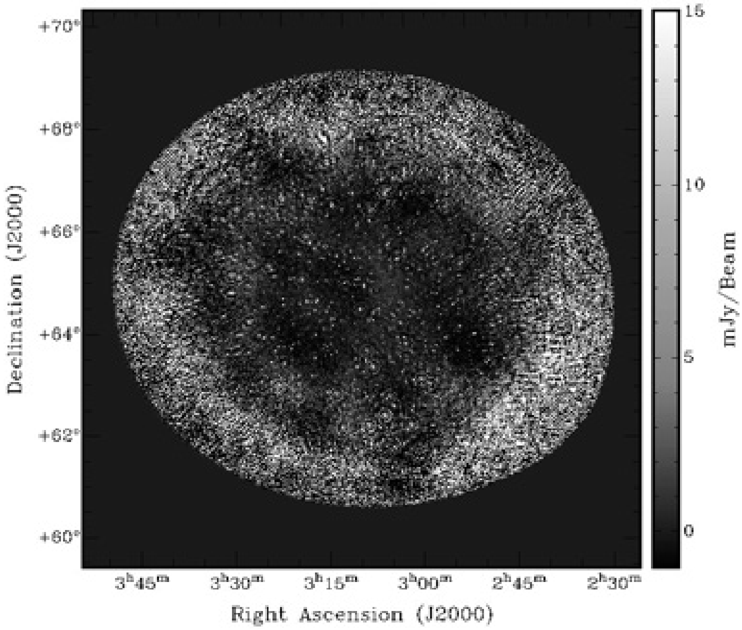

FIGURE 2.10: LOFAR broadband image centered at 150 MHz, showing multi-scale fluctuations in synchrotron emission directly tracing interstellar turbulence (Iacobelli et al 2013).

2.5 The Milky Way and nearby galaxies

2.5.1 Probing interstellar turbulence with LOFAR

Iacobelli and Haverkorn proved that interstellar turbulence could be studied through synchrotron fluctuations at low frequencies. The first map of diffuse synchrotron radiation with the LOFAR telescope was published and synchrotron power spectra derived. The maximum fluctuation scale in the Galactic magneto-ionized medium, often equated to the turbulence injection scale, was measured to be relatively small, adding weight to recent evidence that this scale may be much smaller than generally believed.

Using radiopolarimetric observations of the entire Southern sky, Haverkorn and collaborators found a polarized radio counterpart to the Fermi-bubbles in gamma rays. These observations strongly suggest that these gigantic bubbles emanating from the Galactic Center are not directly caused by nuclear activity of the super-massive black hole, but instead are a star-formation driven outflow from the Milky

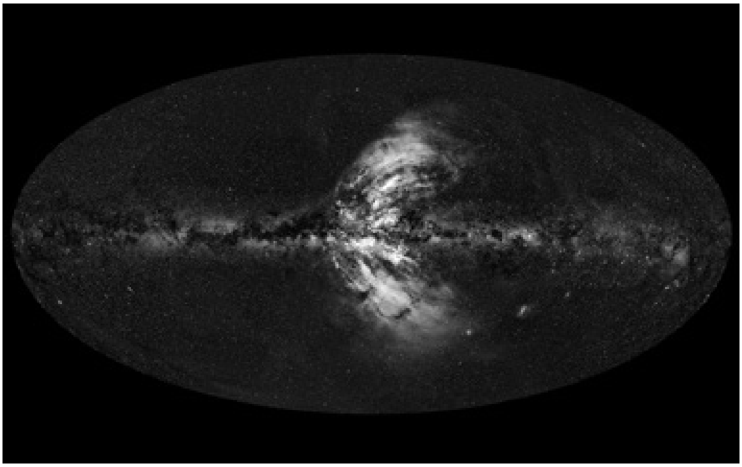

FIGURE 2.11: The new-found outflows of particles (pale blue) from the Galactic Centre, overlaid on an optical all-sky image. The curvature of the outflows is real, not a distortion caused by the imaging process. Credit: radio image - E. Carretti (CSIRO); optical image - A. Mellinger (Central Michigan University); image composition, E. Bressert (CSIRO).

Way's central few hundred parsecs.

2.5.2 High-velocity stars and the dark-matter halo

Our Galaxy can be use as a laboratory to understand galaxy structure, and its formation and evolution. For example, in our Galactic Centre, we have the tightest constraints on the presence, mass and distance of a supermassive black hole (called SgrA*). However, star formation and stellar dynamical processes around SgrA* are still under intense study.

Rossi and collaborators have now been interested for 5 years in a phenomenon that they think can shed light onto those questions as well as the structure and mass of the dark matter halo: hypervelocity stars. These are 3-4 solar mass stars that are observed in the halo ($>$ 30 kpc away), travelling with a radial velocity that exceeds the local escape velocity from the Galaxy, as estimated by models. The star trajectories are consistent with a Galactic Centre origine, and their unusually high kinetic energy may be (only) explained by a dynamical interaction in the deep potential well of SgrA*.

Last year, Rossi and collabortors modelled the velocity distribution of hypervelocity stars, assuming the leading model for their formation: star binaries tidally disrupted by SgA*. In this scenario, one of the star is ejected into the halo, while

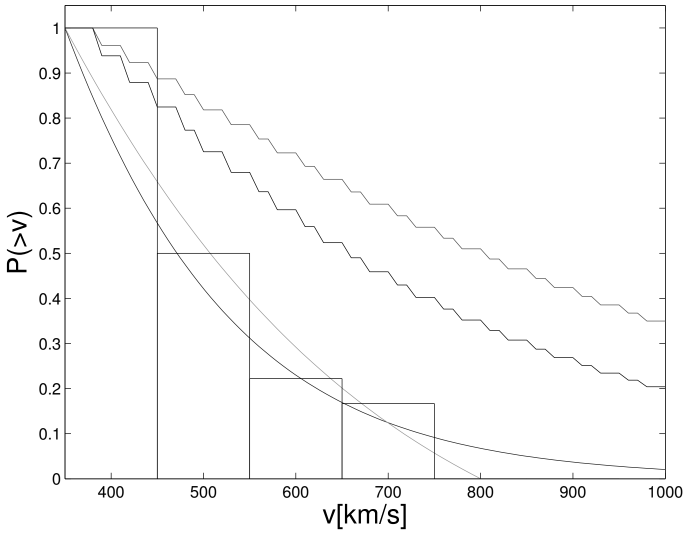

FIGURE 2.12: Cumulative stellar velocity distribution. Black histogram: data taken from Table 1 in Brown et al. (2012). Red and black lines are models with fiducial distribution for the binary period: they clearly do not compare well with data. The blue and green lines, more consistent with data, are models where the distribution of binary periods increases steeply towards longer periods.

the other remains bound to the supermassive black hole. Her modelling showed that data imply a binary population in the Galactic bulge which have a period distribution that favours wider binaries towards tighter ones (see Figure 2.12). This is different from the log normal distibution which is observed in the Solar neighbourhood. It is also inconsistent with the flat logarithmic distribution which is observed in OB associations and commonly assumed in the Galactic Centre. This discovery stimulates and challenges researchers to find how binary formation channels can account for such distribution and whether the vicinity of the supermassive black hole has some bearing. What these authors also show is that current data cannot tightly constrain Galactic potential models, but this will be possible with future hypervelocity star sample, collected with observations by the ESA satellite Gaia.

2.5.3 Galactic Interstellar Medium

Van der Werf completed his HI 21cm study of the Orion Nebula with the NRAO Jansky Very Large Array in B and C configuration, in collaboration with Goss (NRAO, Socorro) and O'Dell (Vanderbildt University, USA). The data reveal HI absorption in the Veil toward the radio continuum of the HII region, and HI emission arising from the Orion Bar photon-dominated region (PDR) and from the Orion-KL outflow. In the Orion Bar PDR, the HI signal peaks in the same layer as the H_2 near-infrared vibrational line emission, in agreement with models of the photodissociation of H_2. The gas temperature in this region is approximately 540 K, and the HI abundance in the interclump gas in the PDR is 5%-10% of the available hydrogen nuclei. Most of the gas in this region therefore remains molecular. Mechanical feedback on the Veil manifests itself through the interaction of ionized flow systems in the Orion Nebula, in particular the Herbig-Haro object HH202, with the Veil. These interactions give rise to prominent blueward velocity shifts of the gas in the Veil. The unambiguous evidence for interaction of this flow system with the Veil shows that the distance between the Veil and the Trapezium stars needs to be revised downward to about 0.4 pc. The depth of the ionized cavity is about 0.7 pc, which is much smaller than the depth and the lateral extent of the Veil. This results reaffirm the blister model for the M42 HII region, while also revealing its relation to the neutral environment on a larger scale.

2.5.4 Nearby starburst galaxies

Van der Werf worked with Rosenberg and Israel to study the excitation mechanisms driving the near-IR H_2 rovibrational lines emission in the well-studies nearby starburst galaxy NGC253, using data from SINFONI at the ESO VLT, with the specifically aim to distinguish between shock excitation and ultraviolet (UV) excitation as the dominant driving mechanism, using Br gamma, H2 and [FeII] as diagnostic emission line tracers. Using the 1-0 S(1)/2-1 S(1) H_2 line ratio as well as several other H2 line ratios and the morphological comparison between H2, Br gamma and [FeII], it was found that excitation from UV photons is the dominant excitation mechanisms throughout NGC253. An upper limit of the percentage of shock excited H2 of about 30% was derived.

2.6 Distant galaxies and clusters

2.6.1 Studying galaxy gass-masses with the Sloan Digital Sky Survey

The determination of gas masses for large samples of galaxies over a range in redshift is challenging with current instrumentation. Brinchmann and collaborators

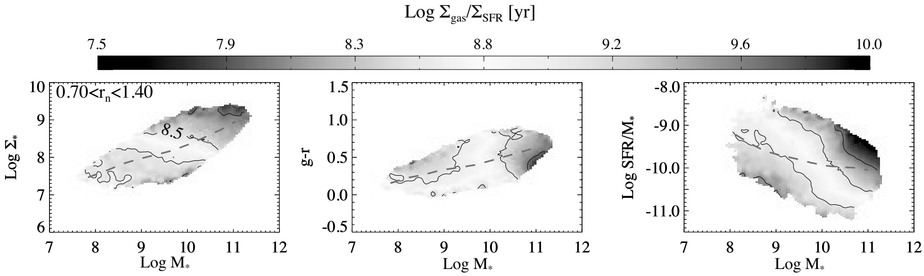

FIGURE 2.13: An inventory of gas and star formation in the central regions of galaxies in the low redshift (z<0.2) Universe. In each panel the colour scale corresponds to the gas mass divided by the star formation rate, the so-called gas depletion time which is the time it would take the galaxy to run out of gas if star formation continues at the current level with no addition of gas. The left-most panel shows how this varies with mass in stars and the mass density of stars, while the central shows this as a function of stellar mass and galaxy rest-frame colour, while the right-most panel shows the same as a function of stellar mass and star formation rate per unit stellar mass. The behaviour is overall smooth but clearly multi-variate in nature.

published an alternative technique that makes use of optical emission line to estimate total gas column densities. This method makes use of the fairly strong temperature sensitivity of some strong emission lines to place constraints on the metal-to-dust ratio in the interstellar medium of the galaxies. By combining this with a simple model for attenuation in galaxies this then provides a constraint on the total gas surface density. By comparison with atomic and molecular gas mass estimates from other sources they show that this proposed method leads to mass estimates that agree with these to within a factor of two, comparable to the observational uncertainties.
They applied this method to a sample of 200,000 star forming galaxies from the Sloan Digital Sky Survey and used this to construct an inventory of gas in the central regions of galaxies in the local Universe. One key result from this investigation was to show that while the gas content in galaxies varies smoothly with the physical properties of the galaxies, no single parameter is sufficient to predict with high accuracy the central gas content.

2.6.2 (Ultra)luminous infrared galaxies

Van der Werf continued the exploitation of the Herschel Comprehehsive (U)LIRG Emission Survey (HerCULES), an Open Time Key Programme on the Herschel

Space Observatory led by Van der Werf. In a paper led by Meijerink (Leiden and Groningen), the first study was made of shock-excited CO gas in NGC6240. The CO ladder is remarkably similar to that of the QSO Mrk231, but the equivalent widths of the CO lines may be used as shock indicators.

Together with Yang (Purple Mountain Observatory, China) and Omont (Institut d'Astrophysique, Paris) Van der Werf reported the first systematic study of the submillimeter water vapour rotational emission lines in (ultra)luminous infrared galaxies based on the Fourier Transform Spectrometer data of Herschel SPIRE. Among the 176 galaxies with available FTS data, 45 have at least one H_2O emission line detected. H_2O is found, for most galaxies, to be the strongest molecular emitter after CO. The luminosity of the five most important H_2O lines is near-linearly correlated with L_{IR}, regardless of whether or not a strong active galactic nucleus signature is present. The average spectral line energy distribution of the entire sample is consistent with a model combining infrared pumping and collisional excitation.

In a paper led by Zhao (IPAC, Pasadena, USA), Van der Werf and collaborators studied the use of the [NII] 204 micron line as a star formation tracer in (ultra)luminous infrared galaxies. [NII] was found to correlate almost linearly with L_{IR} for non-active galactic nucleus galaxies, suggesting that [NII] can serve as a star formation rate tracer which is particularly useful for high-redshift galaxies that will be observed with forthcoming submillimeter spectroscopic facilities such as ALMA. The analysis shows that the deviation from the mean $L_{[NII]}$-L_{IR} relation correlates with tracers of the ionization parameter, which suggests that the scatter in this relation is mainly due to the variations in the hardness, and/or ionization parameter, of the ambient galactic UV field among the sources in the sample.

2.6.3 High redshift submillimetre galaxies

Van der Werf collaborated with Smail and Swinbank (Durham), Weiss (MPIfR) and Walter (MPIA) on the first ALMA observations of a completely identified sample of submillimetre galaxies (SMGs): ALESS (ALMA follow-up of the LABOCA Extended Chandra Deep Field-South Survey). The ALMA data identify the counterparts of the SMGs detected earlier with the LABOCA instrument on the APEX submillimetre telescope. Many SMGs turn out to be double, triple or even quadruple sources. These results lead to a substantial revision of the population properties of SMGs, and are reported in three papers, which discuss the source catalog, the source counts, and AGN content.

Van der Werf is one of the four Principal Investigators (together with Smail, Dunlop, and Halpern) of the SCUBA-2 Cosmology Legacy Survey, the largest project ever carried out on the James Clerk Maxwell 15m submillimetre telescope. This survey produced its first results in 2013. Highlight, discussed in two papers, are the survey results at 450 micon. At this wavelength the survey beam is only 8 arcseconds, yielding direct identifications. The SCUBA-2 results provide a dramatic improvement over Herschel SPIRE surveys at the very similar wavelength of 500 micron (see Figure 2.14), which are dominated by sources confusion, and provide the first reliable cosmic number count at 450 micron.
Van der Werf also worked on spectroscopic follow-up in the (sub)millimetre regime of various lensed high-redshift galaxies, in collaboration with Ivison (Edinburgh) and the Herschel-ATLAS team, Alaghband-Zadeh and Chapman (Cambridge), Boone (Toulouse) and Herschel Lensing Survey team, and Danielson, Swinbank and Smail (Durham). These projects resulted in detections of [CII], [CI] and various CO lines. A highlight is the first high-redshift detection of the CO isotopologues ^{13}CO and $C^{18}O$ in the gravitationally lensed Eyelash galaxy. Here an average velocity-integrated flux ratio of $^{13}CO/C^{18}O \sim 1$ is found, which suggests an abundance ratio of $[^{13}CO]/[C^{18}O]$ which is at least seven times lower than that in the Milky Way. This is suggestive of enhanced C18O abundance, perhaps indicating star formation preferentially biased to high-mass stars.
Van der Werf also worked with Omont (Institut d'Astrophysique, Paris) and Cox (ALMA) on a systematic study of H_2O emission in lensed high-redshift galaxies. The results confirm that H_2O lines are among the strongest molecular lines in high-z ultra-luminous starburst galaxies, with intensities almost comparable to those of the high-J CO lines, and similar profiles and line widths (∼200-900 km s-1). Correcting the luminosities for amplification, the H_2O line luminosities are found to have a stronger than linear dependence on the infrared luminosity, indicate a role of radiative (infrared) excitation of the H_2O lines. This implies that high-z galaxies with $L_{IR} \geq 10^{13}$ Lsun tend to be very strong emitters in water vapour emission lines, that have no equivalent in the local universe.

2.6.4 The host galaxy of the z = 2.4 radio-loud AGN MRC 0406244 as seen by HST

Distant powerful radio galaxies pinpoint rapidly accreting supermassive black holes. Observational evidence suggests that these black holes are situated in massive galaxies some of which are growing at rates of hundreds to thousands of solar

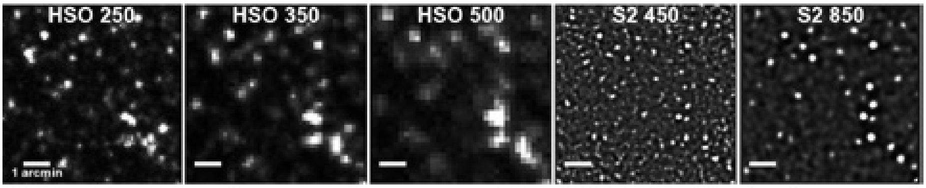

FIGURE 2.14: Patch of sky observe with the Herschel Space Observatory at 250, 350 and 500 micron (confusion-limited images), and with SCUBA-2 at 450 and 850 micron. Note how the higher resolution SCUBA-2 images resolve blends, overcome confusion, and (at 450 micron) yield accurate counterart positions.

masses per year. Hatch, Röttgering, Miley and collaborators have presented multicolour Hubble Space Telescope images of the powerful z = 2.4 radio galaxy MRC 0406244 and model its complex morphology with several components including a host galaxy, a point source and extended nebular and continuum emission. It was suggested that the main progenitor of this radio galaxy was a normal, albeit massive star forming galaxy.

2.6.5 Shocks in merging clusters of galaxies

Stroe, Röttgering, Sobral, van Weeren (Harvard), Ogrean, Bruggen (Bremen) and collaborators continued their multi-wavelengths study of merging clusters of galaxies. These major mergers have been found to produce travelling shock waves which (re-)accelerate ICM electrons. These synchrotron emitting electrons form Mpc-sizes giant radio relics at cluster peripheries.
The cluster 1RXS J0603.3+4214 is a merging galaxy cluster that host a giant radio relic, the Toothbrush. This relic is 1.9 Mpc long and has an unusual linear morphology. Results from a deep XMMNewton observation shows two distinct cluster cores that have survived the merger. The presence of three shocks at or near the locations of the radio relics is confirmed by density and temperature discontinuities. However, the observation poses several puzzles that challenge our understanding of radio relics: (i) at the Toothbrush, the shock Mach number is not larger than 2, in apparent conflict with the shock strength predicted from the radio spectrum; (ii) at the Toothbrush, the shock front is, in part, spatially offset from the radio emission; (iii) at the eastern relic, we detect a temperature jump corresponding to a Mach number of approximately 2.5, but there is no associated surface brightness discontinuity.

The galaxy cluster CIZA J2242.8+5301 contains a spectacular radio relic, 'the Sausage relic. On the basis of Giant Metrewave Radio Telescope (GMRT) and Westerbork Synthesis Radio Telescope (WSRT) spectral index and curvature maps, and radio colour-colour plots were made and compared with model predictions. The data was found to be consistent with the Komissarov-Gubanov injection models, within in which the observed emission is produced by particle acceleration of electrons which subsequently are loosing energy.

2.6.6 The most distant galaxies

Bouwens and Oesch recently discovered six galaxies that likely emitted their light 500 million years after the Big Bang. While astronomers had already known about three specific galaxies that emitted their light at such early times, what was remarkable about these newly discovered galaxies is their exceptional luminosities; the new sources are 10-20 times brighter than previous galaxies observed at these early times. These galaxies provide astronomers with a dramatic illustration of how rapidly the luminosities of galaxies can grow with cosmic time during the early universe.
PhD student Smit also presented the strongest unambiguous evidence for prominent nebular line emission in the spectra of galaxies in the first billion years of the universe. Quantifying the strength of the line emission is important for studies of galaxies at early times, because of the impact such emission can have on the measured fluxes for galaxies at redshifted optical wavelengths. If such line emission is strong, the brightness of distant galaxies would be greater, making galaxies look brighter and more massive than they really are. By measuring the strength of nebular line emission in distant galaxies, Smit has allowed astronomers to measure the mass of galaxies in early universe much more accurately than before.

2.6.7 Studying galaxy and cluster evolution using weak lensing

Jee (UC Davis), Hoekstra and collaborators analysed HST ACS observations of the merging cluster Abell 520 and found that the results are in agreement with their earlier work: there is a region with an anomalously high mass-to-light ratio that coincides with the peak of the X-ray emission. This appears to pose a challenge the naive expectations from standard cold dark matter. Cacciato, Hoekstra and van Uitert (Bonn) continued the analysis of the lensing signal around galaxies

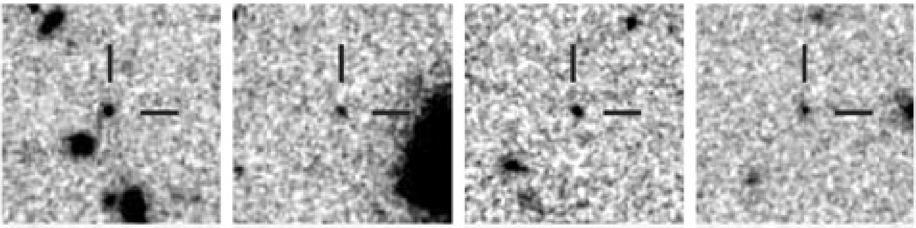

Figure 2.15: Images of four of the most distant galaxies ever seen that were recently discovered by Bouwens and his collaborators. The galaxies of interest are located at the center of each of these image stamps and were observed with the Hubble Space Telescope at a wavelength of 1.6 microns. These sources likely emitted their light just 500 million years after the Big Bang. What is remarkable about these newly discovered galaxies is that they are 10-20 times brighter than previous galaxies discovered at these early epochs and provide a dramatic illustration of how rapidly the luminosities of galaxies in the early universe can grow.

using the overlap of SDSS with RCS2 imaging data. They showed that a halo-model constrained by low redshift SDSS measurements can fit the measurements at higher redshifts, over a wide range in scales. van der Burg, Muzzin, Hoekstra and collaborators studied the distribution of stellar mass in a sample of 10 distant clusters of galaxies. They found that the stellar mass distribution is remarkable compact, suggesting that clusters may grow inside-out.

2.6.8 Tracing the emergence of large scale structure with high-redshift proto-clusters

Rigby, Röttgering, McGee, Miley and collaborators used Herschel/SPIRE observations of 26 high-redshift radio galaxy (HzRG) fields to locate and characterise protocluster-associated galaxy overdensities in the far-infrared. These $z>2$ ancestors of local galaxy clusters are powerful laboratories for tracing the emergence of large-scale structure, and studying the evolution of galaxies in dense environments. Targeting HzRGs has proven to be an efficient tool for selecting them, with the statistics of radio galaxy environment luminosity functions being consistent with every brightest cluster galaxy locally having gone through a HzRG evolutionary phase.

On average, in comparison to blank fields, the fields have a higher than expected surface density of 500 micron sources within 6 comoving Mpc of the central radio galaxy. Restricting the analysis to potential protocluster members only (identified

using a far-infrared colour selection) reveals significant overdensities of galaxies in 2 fields, neither of which are previously known protoclusters; the probability of finding two overdensities of this size by chance, given the number of fields observed, is low. The average radial extent of these structures is 6 comoving Mpc, and comparison with numerical simulations suggests that they have masses $>10^{14}$ M_{solar}, consistent with previously observed protoclusters.
Using HzRGs as beacons is a successful technique, but the number of protocluster found in this way remains small and possibly biased. We have therefore developed a new search method to blindly identify similar far-infrared galaxy overdensities within the large surveys carried out with Herschel. This has resulted in >15 protocluster candidates, selected from 135 sq. deg. of the Herschel-ATLAS. Our HzRG-selected sample provides an ideal consistency check for this analysis; the source excesses displayed by the ATLAS candidates are equal to or greater than the largest ever seen at z>2. Follow-up observations using a range of facilities (WSRT, GMRT, VLA and WHT) are in progress to confirm the nature of these identified overdensities.

2.7 Theoretical studies of galaxies and large scale structure

2.7.1 Physical properties of simulated galaxy populations at z = 2

Haas, Schaye, and collaborators used hydrodynamical simulations from the OWLS project to investigate the dependence of the physical properties of galaxy populations at redshift 2 on metal-line cooling, feedback from star formation and active galactic nuclei (AGN), the assumed star formation law, the equation of state imposed on the unresolved interstellar medium, the stellar initial mass function, the reionization history and the assumed cosmology.
They found that while the normalization of the matter power spectrum strongly affects the galaxy mass function, it has a relatively small effect on the physical properties of galaxies residing in haloes of a fixed mass. Reionization suppresses the stellar masses and gas fractions of low-mass galaxies, but by z = 2 the results are insensitive to the timing of reionization. The stellar initial mass function mainly determines the physical properties of galaxies through its effect on the efficiency of the feedback, while changes in the recycled mass and metal fractions

play a smaller role. Radiative losses quench the winds if their initial velocity is too low. If the feedback is efficient, then the star formation rate is inversely proportional to the amount of energy injected per unit stellar mass formed. This can be understood if the star formation is self-regulating, i.e. if the star formation rate increases until the outflow rate balances the inflow rate. The star formation law, i.e. the gas consumption time-scale as a function of surface density, determines the mass of dense, star-forming gas in galaxies, but affects neither the star formation rate nor the stellar mass. This too can be explained by self-regulation: the gas fraction adjusts until the outflow rate balances the inflow rate.

2.7.2 Non-equilibirum ionization and cooling of metal-enriched gas in the presence of a photoionization background

Simulations of the formation of galaxies, as well as ionization models used to interpret observations, generally either assume ionization equilibrium or ignore the presence of the extragalactic background (EGB) radiation. Oppenheimer & Schaye developed a method to compute the non-equilibrium ionization and cooling of diffuse gas exposed to the EGB. The method iterates the ionization states of the 11 elements that dominate the cooling and uses tabulated ion-by-ion cooling and photo-heating efficiencies to update the temperature of the gas. They found that non-equilibrium effects can become very important in cooling gas, particularly below 10^6 K. Photoionization and non-equilibrium effects both tend to boost the degree of ionization and to reduce cooling efficiencies. Cooling efficiencies and diagnostics of the physical state of diffuse gas can become highly inaccurate if ionization equilibrium is assumed or if the existence of the ionizing background is ignored.

2.7.3 AGN proximity zone fossils and the delayed recombination of metal lines

Oppenheimer & Schaye modeled the time-dependent evolution of metal-enriched intergalactic and circumgalactic gas exposed to the fluctuating radiation field from an active galactic nucleus (AGN). Once the proximate AGN turns on, additional photo-ionization rapidly ionizes the HI and metals. When the enhanced AGN radiation field turns off after a typical AGN lifetime (1-20 Myr), the metals remain out of ionization equilibrium for time scales that can significantly exceed the AGN lifetime. They defined this phase as the AGN proximity zone 'fossil' phase and showed that high ionization stages (e.g. OVI, NeVIII, MgX) are in general enhanced, while the abundances of low ions (e.g. CIV, OIV, MgII) are reduced. In contrast, HI re-equilibrates rapidly owing to its low neutral fraction at diffuse densities. They concluded that a large fraction of the metal-enriched intergalactic medium may consist of out-of-equilibrium fossil zones, which would dramatically change the inferred physical conditions and masses of diffuse gases.

2.7.4 A measurement of galaxy halo mass from the surrounding H I Lyα absorption

Rakic, Schaye, Steidel (Caltech) and collaborators measured the dark matter halo masses of $\langle z \rangle \approx 2.36$ UV colour-selected star-forming galaxies by matching the observed median H I Lyα absorption around them, as observed in the spectra of background QSOs, to the absorption around haloes above a given mass in cosmological simulations. They found a minimum halo mass of log10 (M_{min}/M_{Sol}) $= 11.6 \pm 0.2$, which is in good agreement with published halo mass estimates from clustering analyses. One unique strength of this method is that it can be used in narrow field galaxy-QSO surveys, i.e. $\approx 30 \times 30$ arcsec. In addition, they found that the observed anisotropy in the 2D HI Lyα absorption distribution on scales of 1.5-2 Mpc is consistent with being a consequence of large-scale gas infall into the potential wells occupied by galaxies.

2.7.5 On the evolution of the H I column density distribution in cosmological simulations

Rahmati, Pawlik (MPA), Raicevic, and Schaye used a set of cosmological simulations combined with radiative transfer calculations to investigate the distribution of neutral hydrogen in the post-reionization Universe. They found that the densities above which hydrogen self-shielding becomes important are consistent with analytic calculations and previous work. However, because of diffuse recombination radiation, whose intensity peaks at the same density, the transition between highly ionized and self-shielded regions is smoother than what is usually assumed. The predicted neutral hydrogen column density distributions agree very well with the observations. In particular, the simulations reproduce the remarkable lack of evolution in the column density distribution of Lyman limit and weak damped Lyα systems below $z = 3$.

2.7.6 Soft X-ray and ultraviolet metal-line emission from the gas around galaxies

A large fraction of the gas in galactic haloes has temperatures between $10^{4.5}$ and 10^7 K. At these temperatures, cooling is dominated by metal-line emission if the metallicity $Z \leq 0.1\ Z_{\rm Sol}$, and several lines may be detectable with current and upcoming instruments. Van de Voort & Schaye explored this possibility using several large cosmological, hydrodynamical simulations from the OWLS project. They predicted the observability of various lines from gas near galaxies as a function of galaxy mass and distance for a number of proposed X-ray, UV, and optical facilities. Metal-line emission is typically biased towards high density and metallicity and towards the temperature at which the emissivity curve of the corresponding metal-line peaks. This bias varies with radius, halo mass and redshift. Metal-line emission is a promising probe of the warm and hot, enriched gas around galaxies and provides a unique window into the interactions between galaxies and their gaseous haloes.

2.7.7 Stellar radiation feedback in galaxies

Rosdahl worked on simulations of stellar radiation feedback in galaxies, which are used to study how the radiation from stars affects the evolution of galaxies by e.g. regulating their star formation, heating up and pushing away their gas reservoirs, and even generating galactic winds. The simulations are run with RAMSES-RT, a radiation-hydrodynamical version of the cosmological simulations code RAMSES. For the radiation feedback simulations, Rosdahl added new features to RAMSES-RT which are though to be important in galaxy evolution, namely the momentum transfer of photons to the absorbing gas, and the interactions between photons and dust particles. The effects of radiation feedback was then studied in tightly controlled experiments of simulated isolated galaxy disks, where the effects of the different mechanisms of the interaction between light and matter can be studied precisely. The main results of this study is that stellar radiation plays an important role, together with supernova (SN) feedback, to regulate the galaxy evolution, by heating the galaxy gas, which slows down star formation. While radiation pressure may well be important on parsec and sub-parsec scales (that the simulations do not resolve), the simulations show that it does very little on large scales.
Figure 2.16 shows maps of stars, gas density, and temperature (from left to right), face-on and edge-on, of a galactic disk, residing in a 10^{11} solar mass halo, simulated

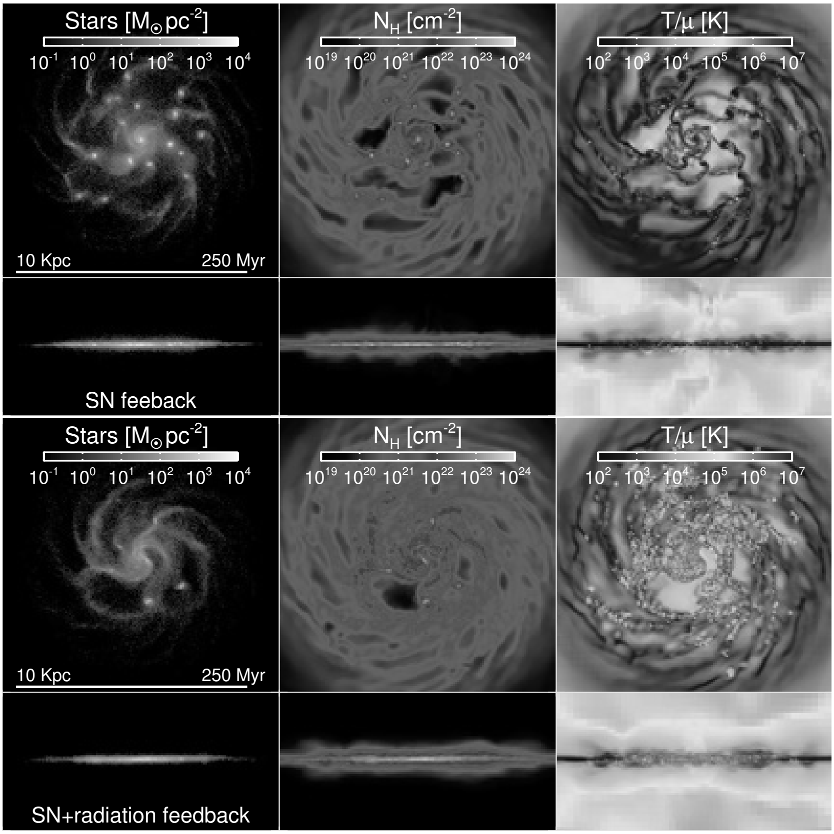

FIGURE 2.16: Maps of a simulated galaxy, in a 10^{11} solar mass halo, with SN feedback only (top panel), and with radiation feedback added (bottom panel). The maps show, from left to right, stellar density, hydrogen gas number density, and gas temperature. The upper row in each panel shows the galaxy face-on and the lower row shows it edge-on. The simulation time (250 Myr) and physical scale (10 Kpc) is indicated at the bottom of the face-on maps showing stellar densities.

without radiation feedback (top panel) and with it (bottom panel). The comparison demonstrates that radiation feedback dramatically reduces the formation of stellar clumps and smooths out the gas distribution.

2.8 The Raymond and Beverly Sackler Laboratory for Astrophysics

The Sackler Laboratory for Astrophysics is one of the largest laboratory facilities, worldwide, fully dedicated to astronomical research. It is a place where physical methods are used to answer chemical questions of astronomical relevance. With eight separate setups a large number of different experiments can be performed, varying from high resolution spectroscopy of molecular radicals and photo-processing or atom bombardment of interstellar ice analogues to the photo-dissociation dynamics of PAHs and ice porosity measurements. These measurements allow to interpret and to guide astronomical surveys and the resulting parameters are needed as input for astrochemical models.

One of the highlights over 2013 was the development and implementation of a series of new ultra-sensitive techniques, based on cavity enhanced broad band spectroscopy. Two super mirrors, with a reflectivity above 99.995 % form an optical cavity and provide the ultimate multipass experiment capable of recording very weak absorption features in expanding plasma. The latter simulates the chemical processes in interstellar clouds. Light is coupled into the cavity using a white light source, or alternatively generated by light of the expanding plasma inside the cavity. Photons exciting the cavity are dispersed using a sensitive spectrometer and in a few seconds up to 250 nm of spectra can be recorded with sensitivities in the ppm domain and with a resolution that is more than sufficient to compare with astronomical observations. The techniques that have been invented are os-IBBCEAS (optical shutter incoherent broad band cavity enhanced absorption spectroscopy) and CESAS (cavity enhanced self absorption spectroscopy). Particularly the latter method also holds potential for direct applications in trace gas detections, illustrating nicely knowledge utilisation of an essentially pure fundamental research project for society.

A special focus has been on the so called DIBs, diffuse interstellar bands. These are optical absorptions observed in the light of reddened stars crossing translucent interstellar clouds. These features are both strong and weak, broad and narrow. DIBs are known for nearly one century by now, but their identification is still lacking. The only common property these nearly 600 different bands share is that none of them has been assigned to a specific carrier. In May 2013 the Sackler Laboratory for Astrophysics hosted the IAU297 “the Diffuse Interstellar Bands” (www.iau297.nl). More than 120 scientists from all over the world joined

FIGURE 2.17: Conference photograph of IAU297 on the Diffuse Interstellar Bands in Noordwijkerhout.

in Noordwijkerhout to discuss the newest results from astronomical observations, laboratory based research, and astrochemical modeling. And even though the DIBs were not identified, many new pieces could be added to the puzzle. Several proposed carriers can be ruled out, other constraints limit the number of possible species involved.

2.8.1 N_2 photodissociation finally unravelled

Molecular nitrogen is one of the key species in the chemistry of interstellar clouds and protoplanetary disks. The partitioning of nitrogen between N and N_2 controls the formation of more complex prebiotic nitrogen-containing species. Li, Heays, and van Dishoeck together with Visser (Michigan), Ubachs (UvA), Lewis and Gibson (ANU) reported the first accurate photodissociation rates for N_2, based on the full high-resolution line-by-line absorption + dissociation spectrum of N_2 over the relevant 912-1000 A wavelength range, by using a quantum-mechanical model which solves the coupled-channels Schrödinger equation. The simulated N_2 spectra are compared with the absorption spectra of H_2, H, CO, and dust to compute photodissociation rates in various radiation fields and shielding functions. The effects of the new rates in interstellar cloud models have been illustrated for diffuse and translucent clouds, a dense photon dominated region and a protoplanetary disk.

2.8.2 Effects of reagent rotation and vibration on reactions

The O (^{3}P) + H_2 $\Rightarrow$ OH + H system has attracted interest for more than half a century by chemical physicists. In addition to its fundamental significance in chemical dynamics, it is also known to be a participant in combustion processes and plays an important role in warm interstellar gas such as shocks, clouds exposed to intense UV radiation, and the inner regions of protoplanetary disks. Li and van Dishoeck, in collaboration with Arasa and van Hemert (Leiden Chemistry), investigated the dynamics of the reverse reaction H + OH (v,J) $\Rightarrow$ O (^{3}P) + H_2 with a series of quasi-classical trajectory calculations and transition state theory methods, based on high quality tential energy surfaces. Accurate OH(v,J) state resolved rate constants in the temperature range 200-2500 K have been presented based on the cross sections. The rate constants for OH in excited vibrational and rotational states are orders of magnitude larger than the thermal rate constants, which needs to be taken into account in astrochemical models.

2.8.3 From PAHs, to graphene: Destroying PAHs in space, one hydrogen at a time

UV photolysis is the main destruction agent of polycyclic aromatic hydrocarbons (PAH) in space. At the Sackler laboratory for astrophysics, Linnartz and Tielens and collaborators have developed the i-POP set up in which molecular cations are stored in an ion-trap and then irradiated with a large number of strong laser pulses. Absorption of multiple UV photons leaves the stored ions highly excited and they will fragment. Sweeping the ion-trap, these fragments can be studied using a time-of-flight mass spectrometer. Figure 1 shows the results on the fragmentation behavior for the PAH, hexabenzocoronene (HBC, C42H18). Fragmentation is dominated by loss of H, as this is the weakest link. Once, HBC has lost (almost) all of its Hs and this PAH has been transformed into a small graphene flake fragmentation of the carbon skeleton ensues. At this point, isomerization of graphene into cages, chains and rings may compete with fragmentation and perhaps even convert the species into fullerenes such as C60.

2.9 The iSPEX citizen science experiments

July 8/9 and Sep 5, 2013 marked the first measurement days of one of the largest-ever citizen science experiments. Several thousand participants of the iSPEX

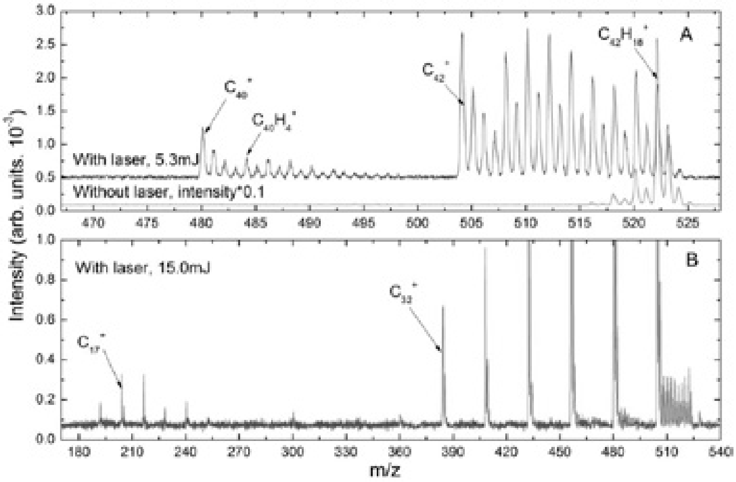

FIGURE 2.18: Fragmentation study of the Polycyclic Aromatic Hydrocarbon, hexabenzocororene (HBC), $C_{42}H_{18}^{+}$, with the i-POP set up at the Sackler Laboratory for Astrophysics. At low laser intensities (top panel), HBC loses H-atoms where loss of an odd number of Hs is preferred over loss of an even numbered H. At high laser fluences, HBC is fully stripped of all of its Hs and the resulting graphene flakes fragment by losing C2 units.

project throughout the Netherlands carried out measurements of atmospheric aerosols - with their smartphone and the dedicated iSPEX add-on and app. The iSPEX technology, consisting of a low-cost yet robust and relatively accurate spectropolarimeter, has been developed within the Astronomical Instrumentation group of the Leiden Observatory as a direct spin-off from instrumentation for direct imaging of exoplanets. The iSPEX team is led by Frans Snik (Leiden) and constitutes a unique collaboration between UL/NOVA with SRON (Netherlands Institute for Space Research), RIVM (National Institute for Health and the Public Environment) and KNMI (Royal Netherlands Meteorological Institute). The basic development of the iSPEX add-on and app was to a large degree carried out by Leiden MSc students Stephanie Heikamp and Ritse Heinsbroek.
The iSPEX project was enabled by winning the Academische Jaarprijs (100 kEuro) in October 2012. Soon thereafter, citizen scientists were recruited with help from with partners Longfonds ("Lung Foundation"), KIJK magazine, Avantes (spectroscopy company) and CNG Net (that operates natural gas stations). 10,000 iSPEX add-ons were produced in February 2013 and a large fraction of those were distributed to participants in the Netherlands. The iSPEX app was approved for the AppStore in April. And then the wait was on for good weather, as the iSPEX

measurement requires cloud-free skies. After a miserable spring also the advent of summer was considerably delayed. But, after the tension had built to a high level, the team could finally announce at a press conference in Leiden that the very first iSPEX measurement day would take place on July 8, 2013. And indeed the weather was great. Most iSPEX team members assembled at the atmospheric measurement station at Cabauw (in the center of the Netherlands) - indeed a location of utmost contrast to most astronomical observatories: green, wet and below sea-level. Participants were requested to carry out iSPEX measurements in the morning and the late afternoon, and at 8 AM approximately one measurement per second was added on the live iSPEX map. The day yielded more than 6,000 measurements in total, more than enough to call the experiment a success. Not only did the data from the first measurement day provide sufficient statistics to analyze the accuracy and added value of iSPEX measurements, but it also proved that such a large-scale involvement of the general public in the scientific practice is realistic (and fun!). The next day yielded more than 1500 spontaneous measurements.

The iSPEX measurement day was truly a national event, and experienced extensive coverage by various media: all major national TV and radio stations, and many newspapers the next morning. On September 5, the team could organize the second national measurement day, with very different atmospheric conditions. All the iSPEX data (>200,000 smartphone photos!) were consequently re-analyzed and interpreted in terms of Aerosol Optical Thickness (a measure for the amount of aerosols in the atmospheric column). An extensive supporting measurement campaign was carried out at Cabauw with instruments including the SPEX instruments (developed by UL and SRON), and serves as reference for the nation-wide iSPEX measurements. The results from the iSPEX measurement days have now been submitted to a peer-reviewed scientific journal. Research into the applicability of iSPEX to obtain unique information on air quality and climate forcing is ongoing.

The iSPEX measurement days in the Netherlands have also generated quite overwhelming interest from all over the globe. The iSPEX team is currently making plans for an international roll-out of the project. Also, iSPEX team members from Leiden are now involved in several international projects that aim to further develop citizen science in general.

FIGURE 2.19: Map of measurements taken with iSPEX.

2.10 AstroPAH Newsletter

The AstroPAH newsletter (http://astropah-news.strw.leidenuniv.nl) was launched in October 2013 with the main goal of acting as a bridge in the interdisciplinary (Astronomy, Chemistry, and Physics) and international community involved in research on Polycyclic Aromatic Hydrocarbons (PAHs) in space and related subjects. AstroPAH emerged as a defining result of the Lorentz Center Workshop The Molecular Physics of Interstellar PAHs that took place in Leiden, The Netherlands, last summer. During the workshop, the idea of a monthly newsletter to keep the PAH community informed of the latest developments in astronomical PAH research was suggested by Aleman (Leiden Observatory). In its monthly editions, AstroPAH publishes abstracts of accepted papers, theses, dissertations, job announcements, and important events of the astronomical PAH community. Each issue also contains two special sections: PAH Picture of the Month, which is self-explanatory, and In Focus, an article covering an interesting PAH related topic (research, experimental facility, interview with a scientist, etc.). The editorial board of AstroPAH is composed of Aleman (executive editor; Leiden Observatory), Candian

Figure 2.20: Covers of the Newsletters on Astronomical PAHs.

(Leiden Observatory), Micelotta (Institut dAstrophysique Spatiale CNRS/Universit Paris-Sud, France), Petrignani (Leiden Observatory and Radboud University Nijmegen), Sciamma-O'Brian (NASA Ames Research Center, USA) and Tielens (editor-in-chief; Leiden Observatory).

Chapter 3

Education popularization and social events

Education, popularization and social events

Chapter 3

3.1 Education

Teaching and training of students is a major priority of Leiden Observatory. In 2013, 53 freshmen started their studies in astronomy. Of this number, 16 (30%) were women, and 21 (40%) pursued a combined astronomy/physics or astronomy/mathematics/computer science degree. The Observatory registered a total number of 114 BSc students at the end of the year, of which 41 (36%) aimed at a combined astronomy/physics degree or astronomy/mathematics degree; 28% of all BSc students is female. There were 41 MSc students, including 9 (21%) women and 14 (34%) of foreign nationality. 28 students passed their propedeutical exam, of which 23 completed the requirements in the nominal one year. There were 11 BSc exams, and 11 MSc exams.

The astronomy programme was selected for a so-called “paper-trail” in the context of the University Audit carried out under the auspices of the NVAO (Nederlands Vlaamse Accreditatie Organisatie). This resulted in a site visit in March, with a particular focus on quality assurance, by an external audit committee. The committee was very favorably impressed. The University Audit was concluded with a positive report in the summer. As result, the astronomy program is eligible for a so-called limited programme review (beperkte opleidingsbeoordeling) in the context of the NVAO accreditation cycle. In spite of the “limited” nature of this review, significant effort was spent on preparing this programme review, which involved a further site visit in December.

Pen continued as the education coordinator taking care of the daily running of tasks. Hoekstra stepped down as the BSc study adviser and Kuijken (1st year students) and Franx (2nd and 3rd year students) took over. Schaye continued as

MSc study adviser. In addition to counseling by the student adviser, incoming students were assigned to small groups meeting at regular intervals with a staff mentor (Snellen, Hogerheijde, Schaye and Portegies Zwart) and a senior student mentor. In the tutor programme, physics and astronomy freshman students were provided on a voluntary but regular basis with coaching by senior students. As part of the Practical Astronomy course, students were taken to the Artis Planetarium in Amsterdam for an introduction to coordinate systems, time and constellations in the sky (Snellen). As part of the second-year training in practical astronomy, 11 students were offered the opportunity to take part in a specially arranged observing trip to the Isaac-Newton-Telescope on La Palma, Canary Islands (Hoekstra and Otten).

In the BSc programme, students in the 2nd year now write a Study Plan, which must be approved by the Student Advisor. The astronomy curriculum is monitored by the Education committee (Opleidingscommissie), which advises the Director of Studies on all relevant matters, and which was chaired by Linnartz. Under the authority of the Education Committee, the lecture course monitoring system was continued. In this system, students provide feedback to lecturers during and after the course. Quality control of all aspects of the exams is the responsibility of the Board of Examiners (Examencommissie) chaired by Snellen. Admission to the master-curriculum for students without a BSc in astronomy from a Netherlands university requires a recommendation by the Admissions committee (Toelatingscommissie) chaired by Portegies Zwart and having Schaye and Rossi as members.

3.2 Degrees awarded in 2013

3.2.1 Ph.D. degrees

A total of 14 graduate students successfully defended their Ph.D. theses in 2013 and were awarded their Ph.D. degree. They are:

Name:	M. de Juan Ovelar
Graduation Date:	12-12-2013
Supervisor:	Keller
Thesis title:	Imaging polarimetry for the characterisation of exoplanets and protoplanetary discs. Scientific and technical challenges

Name:	Kuo-Song Wang
Graduation Date:	10-12-2013
Supervisor:	Hogerheijde/van Dishoeck
Thesis title:	Small scale kinematics of massive star-forming cores

Name:	M. Weiss
Graduation Date:	27-11-2013
Supervisor:	van Lunteren
Thesis title:	The Masses and the Muses: A History of Teylers Museum in the Nineteenth Century

Name:	D. Szomoru
Graduation Date:	21-11-2013
Supervisor:	Franx/van Dokkum
Thesis title:	The Extraordinary Structural Evolution of Massive Galaxies

Name:	S.Rieder
Graduation Date:	30-10-2013
Supervisor:	Kuijken/co: Portegies-Zwart/De Laat(UVA)
Thesis title:	The Clustered Universe
Current position:	Postdoc at the Kapteyn Institute, Groningen, The Netherlands

Name: M. Sadatshirazi
Graduation Date: 15-10-2013
Supervisor: Kuijken/Franx/Brinchmann
Thesis title: Nearby and distant star-forming galaxies as seen through emission lines
Current position: Post-doc at the ETH, Zurich, Switzerland

Name: A. Rahmati
Graduation Date: 15-10-2013
Supervisor: Schaye
Thesis title: Simulating the cosmic distribution of neutral hydrogen and its connection with galaxies
Current position: Postdoc Max Planck Institut fur Astronomie, Heidelberg, Germany

Name: E. Fayolle
Graduation Date: 1-10-2013
Supervisor: Linnartz/Fillion
Thesis title: From Ice to Gas: Constraining the Desorpion Processes of Interstellar Ices
Current position: Post-doc at the Harvard-Smithsonian Center for Astrophysics, Cambridge, Massachusetts, USA

Name: M. Mosleh
Graduation Date: 12-06-2013
Supervisor: Franx
Thesis title: The Stellar Mass-Size Evolution of Galaxies from z = 7 to z = 0

Name: U. Yildiz
Graduation Date: 01-05-2013
Supervisor: Van Dishoeck
Thesis title: Warm and Cold Gas in Low-Mass Protostars: Herschel Space Observatory and Ground-Based Surveys
Current position: Postdoc at NASA Jet Propulsion Laboratory, California, USA

Name: Th. Karalidi
Graduation Date: 23-04-2013
Supervisor: Keller/Stam
Thesis title: Broadband Polarimetry of Exoplanets: modelling signals of surfaces, hazes and clouds
Current : Postdoc at the Steward Observatory in Tucson, Arizona, USA

Name:	B. Nefs
Graduation Date:	27-03-2013
Supervisor:	Snellen/Fridlund
Thesis title:	The Hunt for Red Dwarf Binaries and Hot Planets in the WFCAM Transit Survey

Name:	K. Isokoski
Graduation Date:	26-03-2013
Supervisor:	Linnartz/Van Dishoeck
Thesis title:	Physics and Chemistry of Interstellar Ice
Current :	Sydney, Australia

Name:	J. Bast
Graduation Date:	10-01-2013
Supervisor:	van Dishoeck/Tielens
Thesis title:	Hot Chemistry and Physics in the planet-forming Zones of Disks
Current :	SRON, calibration scientist; Science [&] Technology Coorporation

3.2.2 Master degrees

The following 11 students were awarded Masters degrees in 2013:

Name	Date	Present Position
Paul Langelaan	29-01-13	Trader at FlowTraders.
Pablo Castellanos Nash	26-03-13	Phd Leiden
Sara Khalafinejad	26-05-13	PHD Hamburg
Carla Natario	18-07-13	PhD Engeland
Vincent Oomen	27-08-13	Aviation & Aerospace Professional
Mason Carney	27-08-13	PhD Leiden
Sebastiaan Smeets	27-08-13	Associate consultant at OC&C Strategy Consultants
Ingrid Icke	27-08-13	Cyber Crime Fraude Expert at ABN AMRO
Jens Hoeijmakers	30-08-13	Phd Leiden
Marijke Segers	31-08-13	Phd Leiden
Jeroen Sprangers	26-11-13	Founder of Stichting Studenten Jazz Leiden

3.2.3 Bachelor degrees

The following 11 students were awarded BSc degrees in 2013:

Name	Date	Present Position
Kim Vendel	09-07-13	MSc Leiden, Experimental Physics
Emiel Por	09-07-13	MSc Leiden, Ast & Instrumentation en Theoretical Physics
Sebastiaan Haffert	16-07-13	MSc Leiden, Astronomy & Instrumentation
Nicholas Rasappu	18-07-13	MSc Leiden, SBB & Astronomy
Arthur Bosman	18-07-13	MSc Leiden, Astronomy
Joshua van Houdt	18-07-13	MSc Leiden, Astronomy
Sierk van Terwisga	18-07-13	MSc Leiden, Astronomy
Daniel Hetharia	31-07-13	MSc Leiden, Theoretical Physics
David Bekkers	22-08-13	SBB & Astronomy
Annelies Vreeker	22-08-13	MSc Utrecht, MSc Sustainable development
Jeroen van Gorsel	23-08-13	MSc Leiden, Research in Theoretical Physics

3.3 Academic courses and pre-university programmes

3.3.1 Courses taught by Observatory staff

Bachelor course title	**Semester**	**Teacher**
Introduction astrophysics	1	H. Linnartz
Astronomy lab 1	2	I. Snellen
Planetary systems	2	M. Hogerheijde
Modern astronomical research	3	M. Kenworthy
Stars	4	H. Röttgering
Stars and Cosmology	4	M. Franx
Astronomy lab 2	4	H. Hoekstra
Astronomical Observational techniques	5	C. Keller
Radiative processes	5	E. Rossi
Python cursus	5	E. Deul
Bachelor research project	5-6	B. Brand

Master course title (electives; semesters 7, 8, 9, 10)	**Teacher**
Detection of Light	Kenworthy
Interstellar Medium	van der Werf
Origin and Evolution of the Universe	K. Kuijken
Astronomy from Space	M. Fridlund
Large Scale Structure & Galaxy Formation	J. Brinchmann
IAC '13: Computational Astrophysics	S. Portegies Zwart
Stellar Structure and Evolution	J. Schaye
Observational Cosmology	R. Bouwens
Science and the public: a historical perspective	F. v. Lunteren

3.3.2 Pre-university programme

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

LAPP-TOP programme since its start in 2001. This year the project was coordinated by Kuijken. In eight sessions the following subjects were covered:

Course title	**Teacher**
Extrasolar planets	I. Snellen
The Milky Way and other galaxies	J. Schaye
Practicum I	A. Brown
Building moleculs and planets in the universe	E. van Dishoeck
Black Holes	P. van der Werf
Practicum II	V. Icke
Cosmology	H. Hoekstra
Excursion to the radio telescopes in Westerbork and Dwingeloo	

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

3.3.3 Contact.VWO

Contact.VWO has been in existence since May 2007. Buisman and Van der Hoorn (physics teachers in secondary schools) both work one day a week for the Physics and Astronomy Departments in order to intensify the contacts between secondary schools and the university.
Twice a year Van der Hoorn organizes a production and mailing of posters and organizes three times an informative meeting for physics teachers, starting at 5 p.m. and featuring a lecture on modern developments in physics or astrophysics, an informal dinner with extensive networking between teachers and university workers, and after-dinner subjects dealing with the change from secondary school to university study. Buisman is concerned with school classes (programmes for whole-day visits as well as individual help (assisting >50 pupils with practical work). He also has organized a training session for the module Measuring in Star Systems (Meten aan Melkwegstelsels) which is part of the school curriculum track Nature, Life and Technology (Natuur, Leven en Technologie).
Contact.VWO answers requests for assistance by school pupils or teachers. Buisman also has an appointment for half a day a week as local coordinator of the HiSPARC project, but although related, this is not a part of the activities of

Contact.VWO. Contact.VWO works in close cooperation with the Regionaal Steunpunt Leiden, directed by Jacqueline Hoornweg.

Date	**Activities at Leiden University in 2013 for teachers**
17 Jan	Meeting with teachers: Prof. Dr. Jan Aarts: Electronica met spins
7 Mar	Meeting with teachers: about the new courseware for secondary school pupils
24 Apr	Meeting with teachers: Dr. Michiel Hogendijk: Hoog en Droog: Sterrenkunde met de ALMA-telescoop
13 Nov	Meeting with teachers: theme: Prof. Dr. Edgar Groenen: in resonantie met electronspins
	Activities at Leiden University in 2013 for pupils
25 Jan	Institute day, as preperation for visiting CERN afterwards
14 Mar	Meeting with pupils & teachers: Einsteins Birthday
16 Oct	Educational Seminar Astronomy
	Practical assignment school classes "Discover Exoplanets"
15 Mar	Stedelijk Gymnasium Leiden Science 4U Astronomy
13 Nov	Stedelijk Gymnasium Leiden and Gymasium Paulinum (M¨nster)
15 Nov	Stedelijk Gymnasium Hilversum
20 Nov	Vrijzinnig Christelijk Lyceum, The Hague

3.4 Popularization and media contacts

Brandl

Measuring the Universe with current and future telescopes, Talk, Medellin, Colombia, August 23

Brown

Gaia - Een stereoscopische kaart van de Melkweg, KNVWS Alkmaar, January 25
Unravelling the origins of the Milky Way with Gaia, NVR Gaia mini symposium, Leiden, January 30
Gaia - Een stereoscopische kaart van de Melkweg, KNVWS Utrecht, February 26
Gaia - Een stereoscopische kaart van de Melkweg, KNVWS Groningen, November 15
De Gaia ruimte missie, Mon Plaisir elementary school, Aruba, December 2
Sterrenkunde, IMC Weekendschool, Den Haag, December 8
Gaia - een miljard sterren in 3D, KIJK Live!, Amsterdam, December 9
Gaia: de volgende doorbraak in de sterremkunde, Zenit, October issue
De levensloop van onze Melkweg zien door Gaia, Ruimtevaart, issue March 2013
Interview on Gaia, ANP, December 12

Van der Burg

Sterrenkunde uitzending Emma TV, AMC Kinderziekenhuis, Amsterdam, Juni 12

Van Delft

Boerhaave, gelukkig in de Camp, Rotary Noordwijk-Katwijk, January 31
Beelden van wetenschap: Faust, Frankenstein, Nerd, Nederlandse Vereniging voor Wetenschap- en Techniekcommunicatie, February 14
De laatste jaren van Paul Ehrenfest, Historische Kring Leiden, February 15
Vermakelijke wetenschap, NEMO Amsterdam, March 6
Hoe het verder ging met Museum Boerhaave, Nefarma, March 22
Erfgoed en educatie, UNESCO, March 26
Museum Boerhaave en Petersburg, Nederland-Ruslandjaar, April 9
Over Museum Boerhaave, Stichting Technische Wetenschappen (STW), April 27
The Last Years of Paul Ehrenfest, Ehrenfest symposium, May 31
Hoe het verder ging met Museum Boerhaave, Chiesi, October 15

Hoe het verder ging met Museum Boerhaave, Korvezee gezelschap TU Delft, October 17
De Leidse Instrumentmakersschool, Uitreiking Leidse Innovatieprijs, December 9

Van Dishoeck
Water en de bouwstenen voor leven tussen de sterren, Amsterdam, Paradiso lezing, January 27
Waar komt het water op aarde vandaan?, Leiden, NOB, March 6
Idem, Den Haag, Diligentia, March 4
Building stars, planets and the ingredients for life between the stars, Leiden, Lapp-Top, March 6
Idem, Leiden, HOVO lectures, March 20
Idem, Amsterdam, KNAW, March 25
Idem, Gainesville, University of Florida, April 4
Idem, Leiden, LEAPS students, August 13
Idem, Utrecht, Beta honors symposium, September 17
Idem, Leiden, Pre-University college, November 11
Galactic science with ALMA, San Pedro de Atacama, ALMA inauguration, March 12
Water in de ruimte, Den Haag, Spacepoort, June 12
Dromen van de Melkwe, Leiden, Nacht van Kunst en Kennis, September 14
Is er een tweelingzusje van de Aarde?, Den Haag, Avond Wetenschap en Maatschappij, October 7
Stars can be late parents, ESA Space Science news, January 30
ALMA inauguration interviews, NOS TV , March 12-14
Idem, NOS radio 1, March 12-14
Idem, NOS Oog op Morgen, March 12-14
Idem, BBC TV, March 12-14
Idem, Leiden University Newsletter, March 12-14
Idem, C&EN, March 12-14
Idem, Wall street journal, March 12-14
Idem, Tschech radio, March 12-14
Idem, Planetary Society radio, March 12-14
Idem, El Mercurio, March 12-14
Idem, Asahi Shimbun, March 12-14

Haverkorn
Interview Esta Magazine, March 14
Interview Radio1 "Twee Dingen", March 7
Interview Radio 5 "Hoe?Zo! Radio", Jan 31

Hoekstra
De donkere kant van het Heelal, Studium Generale, TU Twente, January 22
The dark side of the Universe, ASML, Veldhoven, June18
Cosmology, Big History, TU Eindhoven, September 23
idem, Big History, Erasmus University College, Rotterdam, October 4

Hogerheijde
Sterren kijken in de Andes, SchoolTV voor de tweede fase, NTR, March 2013
ALMA: Construction, status, and prospects, Nederlandse Vereniging voor Ruimtevaart, Leiden, May 23
Baby sterreb, Gastlessen OBS De Vogels, Oegstgeest, November 2013

Keller
iSPEX, lecture to VWO students, RSG Lingecollege, Tiel, May 31
The Sky at Night, BBC, December issue

Kenworthy
"How Astronomers Work", talk, Cuba City High School, (Cuba City), Wisconsin, USA, May 06

Kuijken
KiDS: the Kilo-Degree Survey, talk, Nederlandse Astronomenclub, Amsterdam, January 18
De donkere kant van het heelal, plenaire lezing, Werkgroep Natuurkunde Didactiek, Noordwijkerhout, December 14

Maaskant
Spaceflights, when are we going to Mars? Public lecture in planetarium of Natura Artis Magistra, Amsterdam, 2013
Astronomy and art. Public lecture in planetarium of Natura Artis Magistra, Amsterdam, 2013

Planets in the solar system. Public lecture in planetarium of Natura Artis Magistra, Amsterdam, 2013
Museumnacht. Public lecture in planetarium of Natura Artis Magistra, Amsterdam, 2013
Where is the end of the universe? Public lectures in planetarium of Natura Artis Magistra, Amsterdam, 2013
Navigation by the stars. Public lecture in planetarium of Natura Artis Magistra, Amsterdam, 2013

Van der Marel
The growth of small dust grains to planets, KNAW mini lecture, Amsterdam, March 25
ALMA Science: the start of planet formation, NVR ALMA evening, Leiden, May 23
Interview, RTL Nieuws, Leiden, June 6
Interview, CTV Vancouver, Vancouver, June 7
Interview, Labyrint radio, Hilversum, June 9
Interview, Hoe?Zo! radio, Hilversum, June 11

Petrignani
Ruimteonderzoek in het Lab, Spinoza te Paard, talk, Den Haag, February 19
Ruimteonderzoek in het Lab, Spinoza te Paard, video, Den Haag, February 19

Portegies-Zwart
NOS radio 1 "Met het oog van morgen", Febr 15

Röttgering
LOFAR, een nieuwe grote radiotelescoop in Nederland, Gemeentelijk Gymnasium, Hilversum, November 26
LOFAR, een nieuwe grote radiotelescoop in Nederland, Zandvlietcollege, Den Haag, December 19
Radio sterrenkunde, LOFAR en botsende clusters van sterrenstelsels, Open dag oude sterrewacht, March 16

Snellen
De mens in het heelal, oratie, Leiden, November 8

Novel technique boosts hunt for water on exoplanets, Press Release, July 5
New type of telescope may detect extraterrestrial life, Press Release, February 14

Van der Werf
Babys of monsters? Herschel kijkt in het duistere hart van jonge sterrenstelsels, Public Lecture, Amsterdam, May 8

Zeegers
Botsende Rotsblokken, talk, Leiden, March 16
Idem, talk, Leiden, November 15
Machten van tien, talk, Leiden, May 25
History of the Leiden Observatory: stories and anecdotes, talk, Leiden, October 28

3.5 Universe Awareness programme

Miley continued as International Coordinator of the Universe Awareness (UNAWE) programme and Russo continued as UNAWE International Project Manager.
Universe Awareness (UNAWE) uses the beauty and grandeur of the Universe to encourage young children, particularly those from an underprivileged background, to have an interest in science and technology and foster their sense of global citizenship from the earliest age (ages 4 to 10 years). UNAWE has a twofold vision that uses our Universe to inspire and motivate very young children. The excitement of the Universe provides a seductive introduction to science and technology, while the vastness and beauty of the Universe helps broaden the mind and stimulate a sense of global citizenship and tolerance.
Exposing young children to the exciting Universe can light a "spark" that eventually results in their choosing a career in science or engineering. However, the main goal of UNAWE is to excite and fascinate young children at a formative stage in their development and give them a broader perspective on the world. After exciting them, the Universe can be used as a general educational tool, e.g. to encourage reading or math skills by means of space-based stories and problems. UNAWE is unique in that it provides links fundamental research and cutting-edge technology with young children and their teachers.

UNAWE has three main components:

3.5.1 Teacher training

UNAWE provides training activities for teachers and other educators of young children. An important aim is to give primary school teachers the confidence to introduce astronomy and other science topics in the classroom, and to create innovative methods for engaging young children in astronomy.

3.5.2 Educational resources

UNAWE has developed almost 200 hands-on resources that motivate and encourages learning. In 2011 UNAWE materials were awarded the Science Magazine Prize for Online Resources In Science Education (SPORE). Flagship UNAWE resources include the inflatable UNAWE Earthball and the Universe-in-a Box (UiB) activities. To date more than 10,000 Earthballs and 1,000 Universe-in-a-Box have been manufactured and distributed around the world. The UNAWE astronomy news service for children, Space Scoop, in partnership with several international top research institutes, expresses the latest exciting discoveries in ways that children can understand. So far 204 Space Scoops have been created and these have been translated into 27 languages.

3.5.3 International network

This is a global platform for sharing ideas, best practices and resources between educators from around the world. It comprises more than 600 astronomers, teachers, educators and other professionals in 56 countries. Being part of such an international network is particularly useful for teachers in developing countries.
During 2013 UNAWE was very active within Europe. The three-year 2.5 M Euro EU Universe Awareness project to implement UNAWE in 5 EU countries and South Africa, funded by the EU Commission neared its completion. More than 1800 teachers were trained and more than 60,000 children were reached. A successful lobbying campaign in the European Parliament resulted in support from 11 MEPs representing 7 countries and 5 different parliamentary groups. One MEP, Alyn Smith, tabled two parliamentary questions to the Commission requesting continuation of EU-UNAWE.

3.6 Astronomy for Development

As Vice President Emeritus of the International Astronomical Union and Advisor to the Executive Committee, Miley continued to oversee the implementation of the IAU Strategic Plan 2010-2020 “Astronomy for the Developing World”. This Plan foresees a substantial expansion of programmes, and funding, together with a large increase in the number of volunteers. The focus is on a demand-driven coherent mix of sustainable activities. The implementation of the Plan is being coordinated by he IAU Office of Astronomy for Development (OAD) (Director Kevin Govender). This is a joint venture between the IAU and the South African National Research Foundation and the OAD is hosted by the South African Astronomical Observatory in Cape Town. In February Miley rotated from Chair of the OAD Steering Committee to its Vice Chair, while remaining Chair of the IAU Extended Development Oversight Committee (EDOC).

During 2013, the OAD made considerable progress. A global Call for proposals was highly oversubscribed and the IAU EDOC allocated projects recommended by the three OAD Task Forces, Universities + Research, Schools + Children (co-Chair Russo) and Public Outreach. In addition, a third IAU Regional Nodes of the OAD were created in East Africa. The OAD Task Forces and Regional Nodes together with more than 500 OAD volunteers are contributing to the implementation of a demand-driven portfolio of activities. It is expected that fund-raising activities for an expansion of the activities will begin in 2015.
Miley and Russo organised a workshop, lobbied and gave several talks to committees at the European Parliament about the importance of astronomy for education, capacity building and development.

3.7 The Leidsch Astronomisch Dispuut F. Kaiser

The association L.A.D. 'F.Kaiser' is named after the founder of Leiden Observatory, Frederik Kaiser. Every five years, the dies natalis of the association is commemorated. Since the association was founded in 1993, 2013 was such a lustrum year. The major goal of the L.A.D. is to improve the social contacts between undergraduate students and Observatory personnel. Until the end of May, the board of the association consisted of Jeroen van Gorsel (praeses) and Chris Lemmens (vice-praeses) and later was handed down to the current board consisting of Alex Pietrow (praeses), Josha van Houdt (vice-praeses/questor), Queeny van der Spek (ab-actis), Guus de Wit (assessor communication), Lieke van Son (assessor tours) and Emanuele di Gloria (assessor science). The association has risen greatly in popularity with 135 members and an above average amount of activities. Besides our yearly football tournament, which was attended by 12 teams and almost a hundred players we have held an introductory dinner for nearly 50 freshmen, an excursion to the NASA exhibition with 30 people, and two well attended movie nights. We also celebrated Kaisers birthday by means of cake in the Kaiserlounge Besides that we have started an observing poule for students who want to observe in the old observatory, with over 30 participants. More outreach and education was provided by a lecture on the history of astronomy by Hans Hooijmaijers (Museum Boerhaave) and a lecture on the history of the old observatory with stories and anecdotes by Sascha Zeegers (Leiden University), both well attended. Since this year we also have obtained access to a mobile planetarium, which is used during the open days at the old observatory and once a year gets deployed in the university for students. Another main goal of L.A.D. F.Kaiser is to popularize astronomy amongst the public, something which we achieve by means of tours and open days in the old observatory. This year we have done over 96 tours for about 2500 people and also helped with days such as the Sterrenkijkdagen, Museum Night and Sterrewacht Science day, all three attended by a several hundred people. None of these public events would have been possible without the efforts of the student tour guides and volunteers, who we would like to thank for their commitment.

3.8 Vereniging van Oud-Sterrewachters

The 'Vereniging van Oud-Sterrewachters' (VO-S; http://www.vo-s.nl) is the official association of Sterrewacht/Observatory (ex-)affiliates. It has been in existence for over 15 years now and has seen another active year. As usual, the 150 members were offered a variety of activities. The activities included a social drink prior to the Oort Lecture and an annual meeting. This year, the annual meeting was held in Leiden and involved, among others, a visit of the old Sterrewacht buildings in the centre of Leiden. These buildings were recently restored and the attending members received a guided tour of the site. The members furthermore attended several presentations. There was a presentation on the KINGFISH project by prof. Rob Kennicutt, also one on the activities of the Werkgroep Leidsche Sterrewacht (WLS) by Arjan van der Hulst and one by Sascha Zeegers on her activities for which she was awarded the Kaiser Award. This award is given by the VO-S to students for extraordinary achievements is bringing astronomy to the general public. The meeting was attended by 20 members. VO-S members also received a newsletters with Sterrewacht news and were offered an electronic member dictionary.

Appendix I

Observatory staff

Observatory staff

Appendix I

(Between January 1st and December 31st, 2013)

Names, e-mail addresses, room numbers, and telephone numbers of all current personnel can be found on the Sterrewacht website: http://www.strw.leidenuniv.nl/people

Full Professors

E.F. van Dishoeck	
M. Franx	
C.U. Keller	
K.H. Kuijken	
H.V.J. Linnartz	
F.H. van Lunteren	(UL (0.5) / VU (0.3), Teijler's hoogleraar)
S.F. Portegies Zwart	
H.J.A. Röttgering	
J. Schaye	
I.A.G. Snellen	
A.G.G.M. Tielens	
P.P. v.d. Werf	
T. de Zeeuw	(UL (0.0) / Director General ESO)

Affiliate Professors

D. van Delft[a]	(Stichting tot beheer Museum Boerhaave, Museum Boerhaave)
N.J. Doelman	(J.H. Oortfonds)
C.W.M. Fridlund[b]	(J.H. Oortfonds)
M.A. Garrett[c]	
H.J. van Langevelde[d]	

[a]Director Museum Boerhaave
[b]Staff scientist ESTEC / ESA
[c]Director ASTRON, Dwingeloo
[d]Director JIVE, Dwingeloo

Associate Professors, Assistant Professors, senior researchers

R.J. Bouwens	M.R. Hogerheijde	
B.R. Brandl	M.A. Kenworthy	
J. Brinchmann	I.F.L. Labbé	
A.G.A. Brown	E.M. Rossi	
M. Haverkorn[a]	R. Stuik	
H. Hoekstra	R.P.J. Tilanus	UL(0.0)

[a]Staff Radboud University, Nijmegen

Emeriti

A.M. van Genderen	V. Icke
H.J. Habing	F.P. Israel
I. van Houten-Groeneveld	K. Kwee
W.J. Jaffe	J. Lub
R.S. Le Poole	G.K. Miley

Postdocs, Project Personnel, and longterm visiting scientists

Name	*Funding source*	*Name*	*Funding source*
E.F.H. Arends	EU-EUNAWE, TEMI	J.C. Mottram	NWO-VC
F.C.M. Bettonvil	(ASTRON)	A.V. Muzzin	NWO-SPINOZA
J.L. Birkby	NWO-VC	B.D. Oppenheimer	NWO-VI
J.B. Bossa	EU- IEF	S.G. Patel	EU-ERC
M. Cacciato	NWO-VI	A. Patruno	NWO-VI
A. Candian	NWO	F.I. Pelupessy	NWO-M
L.R. Carlson	EU-ERC	M.V. Persson	EU-ERC
K. Chuang	EU-ERC	A. Petrignani	EU-ERC
R.A. Crain	NWO-VC	P.A. Pinilla Ortiz	KNAW
N. Drost	(E-science Center, NWO)	D.A. Rafferty	NOVA
A.K. van Elteren	NWO-M	F.L. Rafferty	NOVA
M.B. Eriksen	EU-ERC	M. Raicevic	NWO VC
M. Fujii	guest (JSPS fellow)	E.E. Rigby	NWO-TOP
I.R. Guerra Aleman	NWO-SPINOZA	M. Rodenhuis	STW
S. Guha Niyogi	NWO-SPINOZA	P.M. Rodrigues Dos Santos Russo	EU-EUNAWE,TEMI
R.H. Hammerschlag	guest (STW)	K.J. Rosdahl	EU-ERC
B. Holwerda	guest (ESTEC)	E. Schmalzl-Meyer	NOVA
B.W. Holwerda	NWO-VC	M. Schmalzl	NOVA
A.N. Heays	UL	W.C. Schrier	EU-EUNAWE
E.M. Helmich	NWO-M	E. Semboloni	EU-ERC
N. Irisarri Mendez	NWO-M	D.R. Serrano Goncalves Sobral	NWO-VI
L. Jilkova	BELSPO, NWO-VI	F. Snik	NWO-ESFRI-ELT
J.T.A. de Jong	NWO-M	J.F.P. Spronck	NWO-VI
A. Juhasz	NWO-ALLEGRO	S. v.d. Tol	NOVA
J.K. Katgert-Merkelijn	guest	L. Venema	guest (ASTRON)
M. Kama	KNAW	M. Viola	NWO-VC, EU-ERC
T.A. van Kempen	NOVA	N. de Vries	NWO-M
P.D. Klaassen	NWO-ALLEGRO	A.J. Walsh	NWO-VI
V.A. Korkiakoski	STW	C. Walsh	EU-ERC,NWO-VI

A. Lesage	NWO-VI	S.M. Weinmann	EU-ERC
T.P.K. Martinsson	NOVA	U. Yildiz	UL
G.S. Mathews	EU-ERC	D. Zhao	NWO-VI
S.L. McGee	NWO-VC	J. Zhen	ERC
R. Meijerink	(RUG)		
J.A. Meisner	NOVA		

Promovendi

Name	*Funding source*	*Name*	*Funding source*
A.S. Abdullah	EU-ERC	K.M. Maaskant	NOVA
H.E. Andrews Mancilla	EU-ERC	N. v.d. Marel	NOVA
J. Bedorf	NWO	C.A. Martinez Barbosa	EU-ITN-GREAT
T.C.N. Boekholt	NWO-VI	F.D.M. Mernier	NWO-SPINOZA, UL
J. de Boer	NWO-VI	T.R. Meshkat	UL / EU-IG
C.A. Bonnerot	NOVA	L.K. Morabito	NWO-TOP
M. Brogi	NOVA	M. Mosleh	UL
M.M. Brouwer	NOVA	S.V. Nefs	NWO-VC
R.F.J. v.d. Burg	NWO-VI	B.B. Ochsendorf	EU-ERC
D.P. Caputo	NWO-VI	G.P.P.L. Otten	NWO-ESFRI-ELT
D.J. Carton	NWO-VC	D.M. Paardekooper	NWO-VI
P. Castellanos Nash	NWO-SPINOZA , UL	B. Pila Diez	NOVA
B. Clauwens	NWO (LION) (guest)	W.M. de Pous	NWO-SPINOZA
N. Clementel	NWO-VC	A. Rahmati	NOVA
S.H. Cuylle	EU-ITN-LASSIE	E.F. Retana Montenegro	NWO-TOP
M.P. van Daalen	UL	A.J. Richings	EU-ITN-COSMOCOMP
M. De Juan Ovelar	NWO-ESFRI-ELT	S. Rieder	NWO
E. Di Gloria	NWO-VI	A.J. Rimoldi	NWO-VI
D. Donevski	ASTRON, UL	M.J. Rosenberg	NOVA
M.N. Drozdovskaya	UL, ERC	M. Sadatshirazi	UL

A. Elbers	ASTRON	F.J. Salgado Cambiazo	EU-ERC
E.C. Fayolle	NOVA	V.N. Salinas Poblete	EU-ERC
G. Fedoseev	NWO-VI	I. San Jose Garcia	EU-ITN-LASSIE
J. Franse	NWO (LION)	J. v.d. Sande	NOVA
M. Fumagalli	EU-ERC	H. Schwarz	EU-ITN-LASSIE
G. Goncalves Ferrari	guest	M.C. Segers	EU-ERC
K.M. Guss	NOVA, UL	C. Shneider	NWO-VI
A.S. Hamers	NWO-VI	C.J. Sifon Andalaft	EU-ERC
D.S. Harsono	NOVA-SRON-UL	R. Smit	NWO-VC
G. van Harten	UU	C.M.S. Straatman	NWO-SPINOZA
S. Heikamp	NWO-ESFRI-ELT	A.H. Streefland	FOM/UL
E. v.d. Helm	NOVA	A. Stroe	NWO-TOP
A.R. Hill	NOVA, UL	D. Szomoru	EU-ERC
H.J. Hoeijmakers	NWO-VI, UL	M.L. Turner	NWO-ITN-COSMOCOMP
R.T.L. Herbonnet	EU-ERC	M. Velliscig	EU-ITN-COSMOCOMP
M. Iacobelli	NWO/UL	S. Verdolini	UL
M. Kazandjian	UL	K. Wang	NOVA
F. Koehlinger	NWO	M.P.M. Weiss	UL/Teylers St.
F. Krause	EU-ERC	T.I.M. van Werkhoven	STW
S. Krijt	UL	W.L. Williams	UL-ASTRON
A.L.M. Lamberts	NWO-Astrochemie	U. Yildiz	NOVA, UL, SRON
X. Li	NWO-Astrochemie	S.T. Zeegers	SRON (guest)
N. Lopez Gonzaga	NWO-VC		

Support Staff

M.K. Boonstra	Assistant Programme Coordinator
J.C. Drost	Management assistant
E. Gerstel	Institute Manager
D.J. Klaassen	Secretary
A.N.G. Pen-Oosthoek	Programme Coordinator BSc and MSc
N. Strookman	Assistant Programme Coordinator
A. Schouten-Voskamp	Management assistant
G.A. v.d. Tang	Secretary
L. v.d. Veld	Secretary

Computer Staff

E.R. Deul	Manager Computer group
D.J. Jansen	Scientific Programmer
N. Verbeek	Programmer
A. Vos	Programmer
E.J. van der Kraan	ICT support
R van Eijk	ICT support

NOVA office

W.H.W.M. Boland	Managing Director
E.F. van Dishoeck	Scientific Director
C.W.M. Groen	Financial Controller
J.T. Quist	Management Assistant

Appendix II

Committee membership

Committee membership

Appendix II

II.1 Observatory Committees

Directorate

(Directie onderzoekinstituut)
H.J.A. Röttgering (director of research)
P.P. van der Werf (director of education)
E. Gerstel (institute manager)

Observatory management team

(Management Team Sterrewacht)

H.J.A. Röttgering
E.R. Deul
A. Schouten-Voskamp (minutes)
I. Snellen (outreach)
E. Gerstel (chair)
F.P. Israel
P.P. van der Werf
A. Brown (faculty council)

Supervisory council

(Raad van Advies)

J.A.M. Bleeker (chair)
B. Baud
J.F. van Duyne
K. Gaemers
C. Waelkens

Research institute scientific council

(Wetenschappelijke raad onderzoekinstituut)

R. Bouwens
B. Brandl
J. Brinchmann
A.G.A. Brown
E.R. Deul
D. van Delft
E.F. van Dishoeck
N. Doelman
M. Franx (chair)
M. Garret
M. Haverkorn
H. Hoekstra
M. Hogerheijde
V. Icke
F.P. Israel
W. Jaffe
C.U. Keller
K.H. Kuijken
M. Kenworthy
H.J. van Langevelde
R.S. Le Poole
H.V.J. Linnartz
J. Lub
F. van Lunteren
G.K. Miley
S. Portegies Zwart
E. Rossi
H.J.A. Röttgering
J. Schaye
I. Snellen
R. Stuik
A.G.G.M. Tielens
P.T. de Zeeuw

Institute council

(Instituutsraad)

E. Deul (chair)
J. Drost
W.J. Jaffe
H. Hoekstra
M. Hogerheijde
T. Pijloo
E. van Uitert

Astronomy education committee

(Opleidingscommissie OC)

H.V.J. Linnartz (chair)
M. Hogerheijde
M. Kenworthy
C.U. Keller
M. Segers
G. de Wit
P.A. Ortiz Otalvaro
A. Jakobs
A. Pietrow
L. Wolters
M. Sunder

Astronomy board of examiners

(Examencommissie)

J. Lub (chair)
J. Aarts (Physics)
J. Brinchmann
F.P.Israel
I. Snellen
B. Brandl

Oort Scholarship Committee

S. Portegies Zwart (chair)
B. Brandl
J. Schaye

Mayo Greenberg Prize committee

G. Miley (chair)
E.F. van Dishoeck
E. Gerstel
H.V.J. Linnartz
J. Lub

PhD admission advisory committee

E. Rossi (chair)
R. Bouwens

MSc admission advisory committee

S. Portegies Zwart(chair)
B. Brandl
J. Schaye

Graduate student review committee

(Promotie begeleidingscommissie)

A.G.G.M. Tielens (chair)
B. Brandl
J. Brinchmann
H. Linnartz
M. Franx

Colloquium committee

J. Brinchmann
M. Kenworthy

Computer committee

R. Bouwens (chair)
R. Crain
M. Schmalzel
R. Stuik
S. Portegies Zwart

Library committee

W.J. Jaffe (chair)
F.P. Israel
J. Lub

Public outreach committee

I. Snellen (chair)
M. van Daalen
R. Smit
J. van de Sande
R. van der Burg

Social committee

E. Fayolle
T. Meshkat
M. Rosenberg
A. van der Tang
N. van der Marel
R. Meijerink
I. Snellen
F. Snik
H. Schwarz

II.2 University Committees (non-Observatory)

Brinchmann
Member, Leids Kerkhoven-Bosscha Fonds
Member, Leids Sterrewacht Fonds
Member, Jan Hendrik Oort Fonds

Brown
Member, Faculteitsraad

Franx
Director, Leids Kerkhoven Bossche Fonds
Director, Leids Sterrewacht Fonds
Director, Oort Fonds
Member, School of Science Science Committee (WECO)

Kuijken
Member, curatorium Teylers Professorship on History of Science

van Langevelde
Chairman, Board of directors Leids Kerkhoven Bosscha Fonds
Member, Board of directors Leids Sterrewacht Fonds
Member, Board of directors Jan Hendrik Oort Fonds

Linnartz
Member, FMD/ELD user committee

Petrignani
Chair, Scientific Organising Committee, Lorentz Center Workshop
Editor, AstroPAH news letter

Röttgering
Member, Curatorium of the professorship at Leiden University "Experimental Astroparticle Physics"

Miley
Chairman, Selection Committee, J. Mayo Greenberg Scholarship Prize

Snellen
Member, LUF International Study Fund (LISF) committee
Member, PR committee, Faculty of Science

van der Werf
Organist of the Academy Auditorium

Appendix III

Science policy functions

Science policy functions

Appendix III

Brandl
PI, METIS (mid-IR instrument for the E-ELT)
Deputy co-PI MIRI (mid-IR instrument for the JWST)
co-I KINGFISH Herschel Open Time Nearby Galaxies Key Project
Member, review board, BMBF Verbundforschung
Member, review board, DLR
Member, NOVA Instrument Steering Committee (ISC)
Member, DAG (Turkish 4m telescope) advisory board
Member, ESFRI board
Member, NOVA MICADO ADC review board

Brinchmann
Legacy Science Coordinator, Euclid mission
Galaxy and AGN evolution science working group coordinator, Euclid mission
Member, MUSE Science team
Coordinator, MUSE data management
Chair, Island Observatories TAC

Brown
Chair, Gaia Data Processing and Analysis Consortium
Member, Gaia Science Team
PI, Gaia Netherlands
Vice President, IAU Commission 8
Member, IAU Commission 37
Member, EU Marie-Curie ITN Gaia Research for European Astronomy Training (GREAT)
Member, Executive Board GENIUS FP7-Space Collaborative Project

Member, Steering Committee ESF-RNP Gaia Research for European Astronomy Training (GREAT)

Candian
Editor, AstroPAH Newsletter

Van Delft
Member, National UNESCO committee
Member, History of Science committee KNAW
Member, jury Huijbrechtsenprijs, Avond van Wetenschap en Maatschappij
Member, Nederlandse Maatschappij der Letterkunde
Member, (directeur) Hollandsche Maatschappij der Wetenschappen
Member, Interdisciplinary Program Board Lorentz Center / NIAS
Ambassador Platform btatechniek
Chairman, Caecilia Foundation (Friends of Museum Boerhaave)
Chairman, bestuur Nederlandsch Natuur- en Geneeskundig Congres
Chairman, Board Stichting Technolab, Leiden
Member, Raad van Toezicht Stichting RINO, Leiden
Member, Ondernemersfonds Leiden
Member, Govering Board Stichting Historie der Techniek

van Dishoeck
Scientific Director, Netherlands Research School for Astronomy (NOVA)
Co-Editor, Annual Reviews of Astronomy & Astrophysics
Member, ESA Space Sciences Advisory Committee (SSAC)
Member, Gebiedsbestuur Exacte Wetenschappen (GB-E)
Member, National Committee on Astronomy (NCA)
Chair, Harvard astronomy department visiting committee
Member, MPIA-Heidelberg Fachbeirat
Member, ETH Dept. of Physics review committee
Co-PI, European JWST-MIRI consortium
President, IAU Division H Interstellar Matter and the Local Universe
Coordinator, Fundamentals of Science profile area Leiden University
Member, Herschel-HIFI Science team
Coordinator, Herschel-HIFI WISH Key Program

Guerra Aleman
Executive Editor, AstroPAH Newsletter
Member, Herschel Planetary Nebula Survey (HerPlaNS) Team

Franx
Coordinator, Nova network 1 science team
Member, KNAW sectie physics and astronomy
Member, James Webb Space Telescope Science Working Group
Member, NIRSPEC Science Team
Member, MUSE Science Team

Haverkorn
Member, program Committee Westerbork Radio Synthesis Telescope
Chair, LOFAR Galactic Science Working Group Magnetism Key Science Project]
Member, LOFAR Magnetism Key Science Project
Member, LOFAR Surveys Key Scienc Project
PI, Southern Twenty-centimeter All-sky Polarization Survey consortium
PI Galactic Science, Southern Polarization All-Sky Survey consortium

Hoekstra
Member, Science Advisory Committee, Isaac Newton Group
Member, Panel NWO panel vrije competie
Euclid Consortium Coordinator
Member Lorentz Center Astronomy Advisory Board
Lead, Euclid Weak Lensing Science Working Group
Member, Euclid Consortium Coordination Group

Hogerheijde
Member, ALMA European Regional Center Coordinating Committee
Secretary/treasurer, Board of Directors Leids Kerkhoven-Bosscha Fonds
Secretary/treasurer, Board of Directors Leids Sterrewacht Fonds
Secretary/treasurer, Board of Directors Jan Hendrik Oort Fonds

Keller
Chair of the Board, Isaac Newton Group of Telescopes
Co-Chair, Planetary and ExoPlanetary Science (PEPSci) Network, NWO, The

Netherlands
Chair, Science Advisory Committee, Kiepenheuer Institute for Solar Physics, Freiburg, Germany
Chair of the Board, Olga Koningfonds, The Netherlands
Member, E-ELT Project Science Team, ESO
Member, Foundation of the Kiepenheuer Institute for Solar Physics, Freiburg, Germany
Member, Scientific Committee of the Istituto Ricerche Solari Locarno (IRSOL) Locarno, Switzerland
Member, editorial board of the journal Astronomische Nachrichten
Member, International Year of Light 2015 Committee in the Netherlands

Kenworthy
Rocky Exoplanets Coordinator, NWO Planetary and Exoplanetary Research Programme
Member, Isaac Newton Group Telescope Allocation Committee Member
Organiser, NOVA Colloquium Organiser

Kuijken
Scientific Delegate from the Netherlands, ESO Council
Member, Scientific Strategy Working Group, ESO Council
Chair, ESO contact committee
Member and Vice-chair, Netherlands Committee for Astronomy
PI, ESO KiDS Survey
PI, OmegaCAM project
Co-I, ESO VIKING Public Survey
Co-I, Planetary Nebulae Spectrograph project
Board Member, Physics Society Diligentia (the Hague)
Board Member, Kapteyn Fonds (Groningen)
Member, European Research Council Starting Grants Panel

Linnartz
Board member, European Task Force for Laboratory Astrophysics
Research coordinator, FP7 ITN 'LASSIE' (Laboratory Astrochemical Surface Science In Europe)
Theme coordinator, NWO-EW/CW 'DAN' (Dutch Astrochemistry Network) Editor, CAMOP (Comments on Atomic, Molecular and Optical Physics / Physica

Scripta)
Chair LOC and member SOC, FD168 Dust, Ice and Gas
Member SOC, IR Plasma Spectroscopy Meetings
Member SOC, Molecular high resolution spectroscopy symposium
Member SOC, Laboratory astrophysics session, IAU GA Honolulu 2015
External advisor, RSC/RAS Astrophysical Chemistry Group
Workgroup leader, FOM group FOM-L-027
Member, NWO-CW "Spectroscopy and Theory"
Member, HRSMC research school

Lub
Member Board Astronomy and Astrophysics
Penningmeester Nederlandse Astronomenclub

van Langevelde
Member, Consortium board of directors European VLBI Network
Member, RadioNet Board and Executive Board
Coordinator, NEXPReS (Novel EXploration Pushing Robust e-VLBI Systems)
Member, European SKA Consortium
Member, of the Dutch URSI committee
Chairman, Board of directors Leids Kerkhoven Bosscha Fonds
Member, Board of directors Leids Sterrewacht Fonds
Member, Board of directors Jan Hendrik Oort Fonds
Member, SKA klankbordgroep NL
Member, ALMA Scientific Advisory Committee (ASAC)
Member, ALMA European Scientific Advisory Committee (ESAC)
Member, SKA Science Working Group Cradle of Life

Miley
Vice President Emeritus, International Astronomical Union (Education and Development)
Chair, IAU Extended Development Oversight Committee
Chair, Steering Committee, IAU Office of Astronomy for Development (OAD)
International Coordinator, EU Universe Awareness FP7 Project
Chair, LOFAR Survey Science Group, Highest Redshift Objects
Trustee, Associated Universities, Inc. (AUI- managing body of US National Radio Astronomy Observatory)

Member, Executive Committee International Astronomical Union
Member, Advisory Panel on Astronomy to the South African Minister for Science and Technology
Member, UK South Eastern Universities Physics Network (SEPNET) Scientific Advisory Committee
Member, Board of Governors of the LOFAR Foundation
Member, Core Team, LOFAR Surveys Key Project

Mottram

Co-chair, Lorentz Center Oort workshop "High-Mass Star Formation, From Large to Small Scales in the Era of Herschel & ALMA"

Portegies-Zwart

Editor, Spinger open access journal "Computational Astrophysics and Cosmology Visiting professor", RIKEN/Tokyo University (ELSI institute)
Member of the Scientific Steering Committee, PRACE

Rigby

Member, SOC for Workshop on Infra-red galaxies, Socit Franaise dAstronomie & dAstrophysique
Member, Herschel Extragalactic Legacy Programme management committee
Member, Square Kilometre Array: Low Frequency tiger team

Röttgering

Member, ASTRON Science Advisory Committee
Member, XMM Large Scale Structure Survey Consortium
PI, DCLA (Development and Commissioning of LOFAR for Astronomy) project for the scientific preparation of science with LOFAR at 4 partaking Netherlands universities
PI, LOFAR surveys: Opening up a new window on the Universe
Member, LOFAR's NL-LAC, national LOFAR steering committee
Member, Euclid consortium board
Member, Herschel H-ATLAS survey
Member, Board LOFAR International Telescope
Member, SKA Science working group on radio continuum surveys
Member, NL-SKA contact committee

Member, Board Holland Space Cluster
Member, NOVA Board

Schaye
Member of the steering committee, Virgo Consortium for cosmological supercomputer simulations
Co-Investigator, MUSE (Multi Unit Spectroscopic Explorer)
Key researcher, NOVA (the Dutch research school for astronomy)
Member, MUSE science team
Member, LOFAR Epoch of Reionization science team
Member, EUCLID cosmological simulations working group
Member, Editorial Board, Scientific Reports
Node coordinator, Cosmocomp EU-RTN
Member, Scientific Organizing Committee, "Circumgalactic medium-galaxy interface", Leiden
Member, Scientific Organizing Committee, "Intergalactic interactions", Edinburgh, UK
Member, Scientific Organizing Committee, "Challenges in UV Astronomy", Garching, Germany
PI, OWLS collaboration (OverWhelmingly Large Simulations)
PI, EAGLE collaboration (Evolution and Assembly of GaLaxies and their Environments)

Snellen
Member, PLATO consortium
Member, ESA ECHO science study team
Member, METIS consortium
Board member, Nederlandse Astronomen Club
Reviewer, Templeton Foundation
Member, NWO Rubicon Committee

Tielens
Member KNAW, sectie Physics and Astronomy

van der Werf
Principal Investigator, SCUBA-2 Cosmology Legacy Survey
Principal Investigator, Herschel Comprehensive ULIRG Emission Survey

Co-investigator, HIFI
Co-investigator, MIRI
Member, METIS Science Team
Member, STFC Herschel Oversight Committee
Member, TAMASIS Network
Project Scientist, AMKID submillimeter camera

Appendix IV

Workshops, colloquia and lectures

Workshops, colloquia and lectures

Appendix IV

IV.1 Workshops

Most of the workshops were held in the Lorentz Center, an international center which coordinates and hosts workshops in the sciences. In 2013 the Leiden astronomers contributed to the following workshops:

Januari 16 - 18
WISH Team Meeting 2013 in Ringberg
Organizer: van Dishoeck

June 10 - 13
Astronomy, Radio Sources and Society: The Wonderful Century
Organizer: Röttgering

June 19 - 21
Leiden Summer CGM-Galaxy Interface Workshop
Organizer: Oppenheimer

October 18 - 19
WISH Team Meeting October 2013
Organizers: van Dishoeck

January 14 - 18
Imaging the Low Frequency Radio Sky with LOFAR
Organizers: Orru, Morabito, Jackson, Röttgering, Wise

January 21 - 25
High-Mass Star Formation, From Large to Small Scales in the Era of Herschel & ALMA
Organizers: Fuller, Kaper, Klaassen, Longmore, Mottram, van der Tak

January 21 - 25
A New View of Accretion onto Sgr A*
Organizers: Baganoff, Bower, Gammie, Goldwurm, Markoff, Nowak

February 4 - 8
Hands-on Workshop on Computational Astrophysics
Organizers: van Elteren, McMillan, Portegies Zwart

February 18 - 22
Magellanic Cloud Star Formation: From the Milky Way to Distant Galaxies
Organizers: Carlson, Gallagher, Lada, Meixner, Nota, Tielens

February 25 - March 1
The PN.S: Future Projects and Ideas
Organizers: Arnaboldi, Chies Santos, Coccato, Kuijken, Napolitano

April 22 - 26
What Regulates Galaxy Evolution?
Organizers: De Lucia, Muzzin, Weinmann

May 6 - 10
Galaxy Formation From z=5 to z=0
Organizers: van Dokkum, Franx

July 22 - 26
The Triggering Mechanisms for Active Galactic Nuclei
Organizers: Tadhunter, Ramos Almeida, Alexander, Ellison, Holt, Morganti

July 29 - August 2

The Molecular Physics of Interstellar PAHs

Organizers: Allamandola, Petrignani, Tielens

August 5 - 9

New Challenges for Early Universe Cosmologists

Organizers: Hoekstra, Komatsu, Meerburg, Pajer, Schalm, Silverstein, Spergel, Verde

IV.2 Endowed Lectures

May 30 (University Auditorium)
Oort Lecture: Life and the Universe: from Astrochemistry to Astrobiology
Louis Allamandola (Space Science and Astrobiology Division, NASA Ames Research Center, California, USA)

Oct 22 (De Sitter Lecture Hall)
Sackler Lecture: The fast track to finding an inhabited exoplanet
David Charbonneau (Department of Astronomy, Harvard University, Cambridge, USA)

IV.3 Scientific Colloquia

Date	Speaker (affiliation)	Title
17/01/13	Jelle Kaastra (SRON, Utrecht)	A deep look into AGN: accretion and outflow of gas in Mrk 509
24/01/13	Vivienne Wild (School of Physics and Astronomy, University of St Andrews)	Gas-rich mergers and the growth of the red sequence
07/02/13	Bas Nefs (Leiden Observatory)	The Hunt for Red Dwarf Binaries and Hot Planets in the WFCAM Transit Survey [PhD Colloquium]
28/02/13	Alberto Sesana (Albert Einstein Institute, Max Planck Institute)	Massive black hole binaries: formation, dynamics and gravitational waves
04/03/13	Umut Yildiz (Leiden Observatory)	Low-mass star formation using high-J CO and O2 lines with Herschel [PhD Colloquium]
07/03/13	Ted Bergin (University of Michigan)	Herschel observations of EXtra-Ordinary Sources: Exploring the Molecular Universe with Broad-Band Spectroscopy [NOVA Speaker]

14/03/13	Steven Rieder (Sterrewacht Leiden)	Clusters, the Universe and Everything [PhD Colloquium]
21/03/13	Andrew King (U. Leicester)	
09/04/13	Moein Mosleh (Leiden Observatory)	The Stellar Mass-Size Evolution of Galaxies from z=7 to z=0
11/04/13	Douglas Heggie (University of Edinburgh)	Stellar-mass black holes in globular clusters
18/04/13	Henrik Beuther (MPIA, Heidelberg)	High-mass star formation: From Milky Way structure to small-scale collapse
25/04/13	Stefan Gillessen (MPE)	Watching a gas cloud disrupt on its way towards the supermassive black hole at the Galactic Centre
02/05/13	Avishay Gal-Yam (Weizmann Institute of Science)	Super Luminous and Unusual Supernovae
07/05/13	Nick Kaiser (Institute for Astronomy, University of Hawaii)	
21/05/13	Ali Rahmati (Leiden Observatory)	The cosmic neutral hydrogen distribution and its connection to galactic ecosystems
23/05/13	George Efstathiou (Institute of Astronomy, Cambridge University)	First Cosmological Results from Planck
30/05/13	Mark Gieles (Surrey University)	The life cycle of star clusters in a tidal field
06/06/13	Kathryn Johnston (Columbia University)	Dissecting the Galactic Halo [NOVA Speaker]
13/06/13	Andreas Burkert (U. Munich)	Self regulated star formation in galactic disks and the mystery of the long universal gas depletion timescale.
20/06/13	Edith Fayolle (Leiden Observatory)	From ice to gas: molecule reservoir in star forming regions [PhD Colloquium]
27/06/13	Daniel Szomoru (Leiden Observatory)	The extraordinary structural evolution of massive galaxies [PhD Colloquium]

05/09/13	Shri Kulkarni (California Institute of Technology, Pasadena, USA)	Booms, Burps & Bangs: The Dynamic Universe
19/09/13	Renyue Cen (Princeton University)	Insights from high-resolution large-scale cosmological hydrodynamic simulations
24/09/13	Kuo-Song Wang (Leiden Observatory)	Small scale kinematics of massive star-forming cores [PhD Colloquium]
26/09/13	Jay Farihi (University College London)	Archaeology of Exo-Terrestrial Planetary Systems
10/10/13	Richard de Grijs (Kavli Institute for Astronomy and Astrophysics, Peking University, China)	Disruptive processes: from star clusters to binary systems
11/10/13	Maryam Shirazi (Leiden Observatory)	Nearby and distant star-forming galaxies as seen through emission lines
17/10/13	Daniela Calzetti (University of Massachusetts)	Nearby Galaxies: Evolution in your Neighborhood
22/10/13	David Charbonneau (CfA Harvard)	The fast track to finding an inhabited exoplanet
24/10/13	Roberto Maiolino (Cavendish Laboratory, University of Cambridge)	The quenching of star formation throughout the cosmic epochs
14/11/13	Maria de Juan Ovelar (Leiden Observatory)	Ground based polarimetry for the characterisation of exoplanets and their environment [PhD Colloquium]
21/11/13	Paul Crowther (Sheffield)	The most massive stars in the Local Universe
28/11/13	Tim van Werkhoven (Leiden Observatory)	Adaptive optics: from telescopes to microscopes [PhD Colloquium]
05/12/13	Rob van Gent (Utrecht University)	Al-Sufi's Book on the Images of the Fixed Stars and its Influence on Islamic and Early-European Celestial Cartography

12/12/13	Mike Barlow (University College London)	Dust and molecules in supernovae and supernova remnants

IV.4 Student Colloquia

Date	**Speaker**	**Title**
01/28/13	Sebastiaan Smeets	The MASCARA Project
05/02/13	Pablo Castellano-Nash	C60
05/27/13	Joris Voorn	SED vs CMD Comparing SED based models for galaxy evolution to CMD based models
06/17/13	Mason Carney	Warm Gas in Protoplanetary Disks: Using CO(6-5) emission to trace heating in disks around T Tauri and Herbig young stellar objects
06/19/13	Saskia van den Broek	The Hunt for Red Galaxies: Discovery of a z = 7.7 red & dead galaxy or maybe not?
06/24/13	Jens Hoeijmakers	Prototyping LOUPE: Spectropolarimetry of Earth from the surface of the Moon
06/28/13	Marijke Segers	Weak gravitational lensing by GAMA galaxy groups from KiDS images
07/05/13	Ingrid Icke	Detecting Earth-sized exoplanets from CoRoT data

IV.5 Colloquia given outside Leiden

Bouwens

Establishing the SFR density at z$\sim$9 from searches for Galaxies behind Lensing Clusters: Advantages of a Differential Approach; Space Telescope Science Institute, Baltimore, United States; April 16

The Highest Redshift Galaxies, Ringberg Castle, Tegernsee, Germany; May 16

The Highest Redshift Galaxies, Measuring the Growth of Galaxies in the Early Universe, National Astronomy Conference, Lommel, Belgium; May 17

Galaxy Build-up in the First Two Billion Years of the Universe, Institut dAstrophysique, Paris, France; June 28
What Current Observations can Teach Us about the Properties of Galaxies in the Early Universe, European Week of Astronomy & Space Science, Turku, Finland; July 8
Characterizing the Colors, Physical Properties, and Specific Star Formation Rates in the Galaxies that Reionized the Universe, Uluru, Australia; July 16
Exploring Cosmic Dawn at z∼7-12, Cavendish Observatory, Cambridge, United Kingdom; September 3
Halpha fluxes and accurate SFR measurements for z∼4-7 Galaxies, University College London, London, United Kingdom; September 18
What we can learn about the metallicities and stellar populations of very high-redshift galaxies from the observations, Paris Meudon, Paris, France; October 24

Brandl
METIS, ESO, Garching, Germany; February 27
Zooming in on Starbursts, Arcetri Observatory, Italy, May 29
A multi-component ISM model for NGC 3184: Origin of the [CII], KINGFISH meeting, Leiden, October 14

Brinchmann
Euclid Legacy, Euclid consortium meeting, Leiden, the Netherlands; May 14
Massive stars in galaxies What ionizes He II?, IAP-Subaru joint international conference, Stellar populations across cosmic time, IAP Paris, France; 27 June 2013
Legacy science with Euclid, the Portuguese Astronomy Meeting, Lisbon, Portugal; July 19
MUSE-WISE Managing Massive IFU Data Sets from the MUSE Instrument on VLT, contributed talk at SciOps 2013, ESAC Madrid, Spain; September 11
Galaxy evolution with Euclid, SKA-Euclid meeting, Oxford, United Kingdom; Sep 18
Star formation, gas and stars - what is the dependence of the Kennicutt-Schmidt relation on physical parameters?, the 2013 Blaauw symposium, Groningen, the Netherlands; October 14
The gas content of galaxies at z<0.2 - Insights from gas estimates for 200,000 SDSS galaxies, Heidelberg Joint Colloquium, Heidelberg, Germany; Dec 03

Brown

Gaia - counting down to launch, Meeting of the Socit Franaise dAstronomie et dAstrophysique, Montpellier, France, June 5
DPAC - counting down to first data, EWASS, Turku, Finland, July 11
Gaia - counting down to launch, The Milky Way as a Laboratory for Galaxy Formation, Aspen, USA, August 6
Gaia - counting down to launch, Gaia Challenge workshop, Guildford, UK, August 19
DPAC data processing: making the Gaia science happen, DPAC/SOC operations workshop, Fuerteventure, Spain, September 11
Gaia - counting down to launch, XXV Congreso Nacional de Astronoma, Mexico City, Mexico, November 1

Candian

Hydrogen loss in the HBC cation, COST, Windsor, UK; April 4
Bay Region in PAH molecules, NASA AMES, Mountain View, USA; May 15
idem, The University of Nottingham, UK; July 9
Hydrogen loss and IR spectroscopy of PAH cations, Radboud Univ., Nijmegen, NL; Nov 20

van der Marel

Planet formation in action: resolved gas and dust images of a transitional disk, 2013 Rocks conference, Waikoloa, USA; April 12 idem, IAUS 299, Victoria, Canada; June 3
idem, CfA Harvard, Boston, USA; June 10
Mind the gap: transitional disks and their host stars, ING, Santa Cruz de La Palma, Spain; August 13
Planet formation in action: the role of dust trapping in transitional disks, Kona, USA; December 9
idem, IfA, Honolulu, USA; December 13
idem, Caltech, Los Angeles, USA; December 26

van der Burg

The Cluster Galaxy Stellar Mass Function at z=1 from the GCLASS Survey, Sexten Center for Astrophysics, Sesto, Italy; July 4
A Census of Stellar Mass in 10 Massive Haloes at z$\sim$1 from the GCLASS Survey,

DARK cosmology centre, Copenhagen, Denmark, December 5
idem, ESO Garching, Munich, Germany; December 13

Van Delft

Museum Boerhaave and the Uses of our Knowledge, Woudschoten History of Science Conference; June 15
Medical Collections in Leiden, Annual Meeting Society of Pelvic Surgeons, Palace Hotel Noordwijk; July 11
Museum Boerhaave: Fears, Friend, Future, colloquium Medical Museion, Copenhagen; August 30
Inventing Europe and Museum Boerhaave, Inventing Europe Workshop, Sorbonne, Paris, September 21
IJveraar, waarheidszoeker, amuseur: Geschiedenis en gedaantes van de wetenschapsjournalistiek,
KNAW-symposium Kweekvlees, kanker en koude kernfusie, Amsterdam, October 31
Museum Boerhaave, Society and the Real Thing, colloquium Positioning Academic Heritage,
Universiteit Gent, November 19
Einstein in Leiden and Princeton, Cleveringa Lecture, Washington, November 26

van Dishoeck

Building stars, planets and the ingredients for life between the stars, Tel Aviv University, Tel Aviv, Israel; May 26 (Sackler lecture)
Idem, Oxford University, Oxford, UK; May 29 (Halley lecture)
Transitional disks: planet formation in action Tel Aviv University, Tel Aviv, Israel; May 27
Idem, Oxford University, Oxford, UK; May 30
Water in space: from interstellar clouds to planet-forming disks, Joint Munich Colloquium, Garching, Germany; June 20
Sweet results from ALMA, Sterrewacht science day, Leiden, the Netherlands; September 9
Zooming into planet-forming zones of disks: sweet results from ALMA Joint Cavendish-IOA colloquium, Cambridge, UK; October 8
Water in space: from interstellar clouds to planets Open University, Milton Keynes, UK; October 9

Fumagalli
How dead are dead galaxies?, EWASS 2013, Turku, Finland, July 9
Idem, 9th Marseille Cosmology Conference, Aix-en-Provence, France, July 25
Idem, University of California at Irvine, USA, December 3
Idem, Carnegie Observatories, Pasadena, USA, December 4
Idem, University of California at Santa Barbara, USA, December 5
Idem, Yale University, New Haven, USA, December 11
Idem, Space Telescope Institute, Baltimore, USA, December 13
Idem, NASA-Goddard Space Flight Center, Greenbelt-MD, USA, December 19

Guerra Aleman
Understanding the Physical and Chemical Processes in PNe with Photoionisation/PDR Models, ChanPlaNS/HerPlaNS Joint Team Meeting & Workshop, La Cristalera, Universidad Autonoma de Madrid, Miraflores de la Sierra, Spain, February 19

Haverkorn
The magnetic Milky Way, seen through rotation measure synthesis, Groningen University, Nov 4
Radioastronomie en Galactisch magnetisme, Technical University Eindhoven, Feb 25
De Magnetische Melkweg, KNAW Amsterdam, Oct 10

Hoekstra
Weak lensing by large-scale structure, ESTEC, Noordwijk, January 18
Idem, Birmingam, UK, February 6
invited review, Cluster masses and profiles, Madonna di Campiglio, Italy, March 18-22
invited review, Dark energy workshop, Clermont-Ferrand, France, April 13
invited review, CosmoLens, Marseille, France, Mary 27-30
invited review, Ripples in the Cosmos conference, Durham, UK, July 22-26

Hogerheijde
Observing protoplanetary disks with ALMA Band 11, ALMA Band 11 workshop, Oxford; March 20
Modeling the chemistry of interstellar clouds, EWASS 2013, Turku; July 10

The role of angular momentum in low- and high-mass Galactic star formation, Blaauw Symposium, Groningen; October 14

Keller

Astronomische Polarimetrie, 28. Optik-Kolloquium ITO Stuttgart, Germany; February 27
Fotonen Slijpen voor de Sterrenkunde, KNAW Mini-Symposium on Revolutie in de optica: een TOMTOM voor fotonen, Amsterdam, The Netherlands; March 21
iSPEX, The Sense of Contact 15, Soesterberg, The Netherlands; 10 April 10
iSPEX, Dutch-French Seminar on Photonics for the Future, Dutch Embassy in Paris, France; September 25
Integrated High-Resolution Observation through Turbulence, Smart Optical Systems Annual Conference, Delft, The Netherlands; October 30
Extreme Polarimeter: Results and Experience, SPHERE-ZIMPOL Workshop, ETH Zurich, Switzerland; December 9

Kenworthy

APP Observations of Fomalhaut and HD 100546, STScI, Baltimore, USA; April 29
Challenging Exoplanet Formation Models with Direct Imaging and Coronagraphy: Fomalhaut and HD 100546", IRAM/IPAG Seminar, Grenoble, France; November 14

Kuijken

Weak lensing masses of galaxies, Lorentz Center workshop, Leiden; March 1
KiDS: The Kilo-Degree Survey, Annual Euclid Consortium Conference, Leiden; May 14
Idem, Durham, UK; May 24
Idem, PACT, Madrid, Spain; October 23
Future ESO Surveys, at Ripples in the Cosmos, Durham, UK; July 26
KiDS and GAMA, Liverpool, UK; September 9

van Langevelde

The future of the European VLBI Network, Lorentz work Astrophysical Transients, Leiden, 13 May
The Observatory Career, director of the European VLBI facility, NOVA career

dag, Dalfsen 6 July
Address, Sardinia Radio Telescope, Cagliari OT, 29 September
Galactic opportunities: VLBI with the SKA1, SKA CoL SWG, Jodrell Bank, 6 November

Linnartz
Good bye colloquium Prof. W.L. Meerts, Radboud University, January 2013
Invited talk 'ALMA meeting', Copenhagen, January 2013
Invited talk 'First workshop on laboratory astrophysics', Kauai, Februari 2013
Astrophysical colloquium Kapteyn Institute, Groningen, March 2013
Invited talk Gordon Research Meeting 'Chemistry at surfaces', les Diablerets, April 2014
Contributed talk IAU297 'The diffuse interstellar bands', Noordwijkerhout, May 2013
Invited talk 'Free Radical Meeting', Potsdam, July 2013
Lecturer Cosmochemistry, Summerschool, Schwaegalp, August 2013
Invited talk ACS Meeting, Indianapolis, September 2013
Invited talk 'Clustertreffen', Freiburg, October 2013
Colloquium MPI Plasmaphysik, Greifswald, November 2013

Mottram
Waterfalls around Protostars, ESTEC, The Netherlands; March 8
Idem, University of Exeter, UK; May 8
Idem, University of Manchester, UK; May 10
Idem, Open University, UK; May 13
Idem, Cambridge University, UK; May 14
Waterfalls and Fountains, 'The Universe Explored by Herschel' conference, ESTEC, The Netherlands; October 17
Idem, CalTech, USA; October 29
Idem, Harvard CfA, USA; November 8
CO and Dust: The era of Galactic surveys, 'Atomic and Molecular ISM from Galactic to Extragalactic Scales' 1-day meeting, MPE, Garching, Germany; November 18

Rigby
Detecting the highest redshift quasars with SAFARI, SRON, Utrecht, Netherlands;

March 12
Searching for protoclusters in the far-infrared with Herschel/SPIRE, Montpellier, France; June 5
Idem, Astronomy, radio sources & society conference, Leiden, Netherlands, June 13
Idem, Kapteyn Institute, Groningen, Netherlands; August 30
Continuum surveys with SKA1-Low, ASTRON, Netherlands; November 21

Rosdahl
RHD simulations of galactic winds, CRAL - Observatoire de Lyon, Lyon, France, Oct 29

Röttgering
Observations of galaxy cluster mergers with LOFAR, Colloquium, Cardiff, February 27 LOFAR Dalfsen II - Collaboration Science Workshop, Dalfsen, March 19
The impact of merger shocks on the evolution of clusters, Snowcluster 2013: Physics of Galaxy Clusters, Utah, March 24-29
Dust in proto-clusters, KNAW Academy Colloquium FIRSED 2013, Amsterdam, April 3-5
LOFAR busy week, Manchester, April 15-17
LOFAR surveys, H-Atlas team meeting, Cardiff, June 27-28
LOFAR and studies of clusters, starbursts and AGN, Galaxy evolution over five decades, Cambridge, September 3-6
SKA continuum observations of the extragalactic Universe, SKA continuum assessment workshop, Jodrell bank, Sept 9-11 2013
LOFAR and cosmology, Synergistic Science with Euclid and the Square Kilometre Array, Oxford, September 16-18
Radio surveys of the extra galactic sky, The Radio Universe @ Gers (wave)-length, Groningen, November 4-7
LOFAR and studies of clusters and proto-clusters of galaxies, Colloquium, Vienna, Austria, December 16

Schaye
Gas around galaxies , Observatoire de Geneva, Geneva, Switzerland; January 8
Overview of sub-grid models in cosmological simulations, Institute of Astronomy, Cambridge, UK; July 8
Cosmology with small-scale structure: Effects of baryons, Tokyo, Japan; July 25

The effect of baryons on the distribution of dark matter, Trieste, Italy, October 9
Idem, , Trieste, Italy; October 10
Star formation in cosmological simulations , Groningen, the Netherlands; October 14
Cosmological simulations of the formation of galaxies , University of Chicago, Chicago, USA; November 26
Idem, Stanford University, Palo Alto, USA; December 2
Idem, University of California at Berkeley, Berkeley, USA; December 3

Snellen
Finding Extraterrestrial Life using ground-based high-dispersion spectroscopy, Royal Society, London, UK, March 15
idem, Harvard University, Cambridge, USA, May 21
idem, University of Geneva, Geneva, Switserland, 17 September
idem, University of Groningen, Grongingen, NL, November 18
idem, Royal Observatory Edinburgh, Edinburgh, UK, November 27
idem, University of Bern, Bern, Switserland, December 3
EChO and ground-based characterization of exoplanet atmospheres, ESTEC, Noordwijk, NL, July 2
Combining high-dispersion spectroscopy with high contrast imaging,MPIA, Heidelberg, Germany, November 4

van der Werf
Radiative and Mechanical feeback in (Ultra)luminous infrared galaxies; Koninklijke Nederlandse Academie van Wetenschappen, Amsterdam, Nederland; April 3
The Herschel Comprehensive (U)LIRG Emission Survey (HerCULES); The Universe Explored by Herschel, Noordwijk, The Netherlands; October 15
Radiative and Mechanical feeback in (Ultra)luminous infrared galaxies; School of Physics and Astronomy, Cardiff, United Kingdom; October 30

Appendix V

Grants

Sterrewacht Leiden

Grants

Appendix V

Only grants above €20,000,-

Brown
FP7-SPACE programme, Gaia European Network for Improved User Services, EU, €395,000

Ehrenfreund
EC SPACE, €325,000

Garett
IBM, €20,000

Haverkorn
PhD position, NOVA4, Diffuse emission in the Galactic plane", €207,366

Hogerheijde
TOP-grant Section 1, NWO, Crossing the snowline: effects on planet-formation and legacy in Solar-System comets, €541,500

Keller
PEPSci, NWO, 'The dawn of exoplanet-geology: Studying gas and dust from hot, rocky exoplanets', €206,000
NOVA, 'EPICS', €375,000
NOVA, 'Direct Imaging Techniques with SPHERE/ZIMPOL', €357,725

Labbe
NWO NWO-TOP, €212,000

Linnartz/van Dishoeck
NWO-M: CRYOPAD2: Shining light on interstellar ice, €80,000
NWO-PEPSci: Shining light on bio-molecular evolution: complex organics and comets, €205,000
NOVA4-I&S: Several projects, €425,000

Miley
EU Universe Awareness (European Commission), €2,000,000
Gratama/LUF, €20,000

Patruno
NWO VENI, €800,000

Röttgering
EC SPACE, €200,000
Joint NWO-NRF grant for NL-South-Africa corporation: Scientific exploitation of the new generation of radio continuum surveys €45,000

Schaye
NOVA phase 4, network 1, Simulating the gas around low redshift galaxies, €207,366

Snellen/Keller
NWO PEPSci, "The dawn of exoplanet geology", €219,000

Tielens/Röttgering
NWO NWO-TOP, €635,000

Walsh
NWO VENI, €250,000

Appendix VI

Scientific publications

Scientific publications

Appendix VI

VI.1 Ph.D. Theses

A total of 14 graduate students successfully defended their Ph.D. thesis in 2013 and were awarded their Ph.D. degree. They are in order of date:

M. de Juan Ovelar	Imaging polarimetry for the characterisation of exoplanets and protoplanetary discs. Scientific and technical challenges
Kuo-Song Wang	Small scale kinematics of massive star-forming cores
M. Weiss	The Masses and the Muses: A History of Teylers Museum in the Nineteenth Century
D. Szomoru	The Extraordinary Structural Evolution of Massive Galaxies
S.Rieder	The Clustered Universe
M. Sadatshirazi	Nearby and distant star-forming galaxies as seen through emission lines
A. Rahmati	Simulating the cosmic distribution of neutral hydrogen and its connection with galaxies
E. Fayolle	From Ice to Gas: Constraining the Desorpion Processes of Interstellar Ices
M. Mosleh	The Stellar Mass-Size Evolution of Galaxies from z = 7 to z = 0
U. Yildiz	Warm and Cold Gas in Low-Mass Protostars
Th. Karalidi	Broadband Polarimetry of Exoplanets: modelling signals of surfaces, hazes and clouds
B. Nefs	The Hunt for Red Dwarf Binaries and Hot Planets in the WFCAM Transit Survey
K. Isokoski	Physics and Chemistry of Interstellar Ice
J. Bast	Hot Chemistry and Physics in the planet-forming Zones of Disks

VI.2 Publications in refereed journals

Agnese, R., and 89 co-authors, including **Daal, M.**, **Martinez, C.**; Silicon Detector Dark Matter Results from the Final Exposure of CDMS II; *Physical Review Letters*; 2013; **111**; 251301

Agnese, R., and 88 co-authors, including **Daal, M.**, **Martinez, C.**; Publisher's Note: Silicon detector results from the first five-tower run of CDMS II [Phys. Rev. D 88, 031104(R) (2013)]; *Phys. Rev. D*; 2013; **88**; 059901

Agnese, R., and 88 co-authors, including **Daal, M.**, **Martinez, C.**; Silicon detector results from the first five-tower run of CDMS II; *Phys. Rev. D*; 2013; **88**; 031104

Alaghband-Zadeh, S., and 9 co-authors, including **Meijerink, R.**, **van der Werf, P. P.**; Using [C I] to probe the interstellar medium in z ~ 2.5 submillimeter galaxies; *MNRAS*; 2013; **435**; 1493

Alatalo, K., and 25 co-authors, including **de Zeeuw, P. T.**; The ATLAS^{3D} project - XVIII. CARMA CO imaging survey of early-type galaxies; *MNRAS*; 2013; **432**; 1796

Aliu, E., and 84 co-authors, including **Fumagalli, M.**; Long Term Observations of B2 1215+30 with VERITAS; *ApJ*; 2013; **779**; 92

Allodi, M. A., and 21 co-authors, including **Cuylle, S. H.**, **Linnartz, H.**; Complementary and Emerging Techniques for Astrophysical Ices Processed in the Laboratory; *Space Sci. Rev.*; 2013; **180**; 101

Almenara, J. M., and 49 co-authors, including **Fridlund, M.**; Transiting exoplanets from the CoRoT space mission. XXIV. CoRoT-25b and CoRoT-26b: two low-density giant planets; *A&A*; 2013; **555**; A118

Altay, G., and 4 co-authors, including **Schaye, J.**; The impact of different physical processes on the statistics of Lyman-limit and damped Lyman α absorbers; *MNRAS*; 2013; **436**; 2689

Amendola, L., and 62 co-authors, including **Hoekstra, H.**; Cosmology and Fundamental Physics with the Euclid Satellite; *Living Reviews in Relativity*; 2013; **16**; 6

Appleton, P. N., and 22 co-authors, including **van der Werf, P.**; Shock-enhanced C^+ Emission and the Detection of H_2O from the Stephan's Quintet Group-wide Shock Using Herschel; *ApJ*; 2013; **777**; 66

Aprile, E., and 76 co-authors, including **Brown, A.**; Limits on Spin-Dependent WIMP-Nucleon Cross Sections from 225 Live Days of XENON100 Data; *Physical Review Letters*; 2013; **111**; 021301

Aprile, E., and 80 co-authors, including **Brown, A.**; Response of the XENON100 dark matter detector to nuclear recoils; *Phys. Rev. D*; 2013; **88**; 012006

Arasa, C., and 3 co-authors, including **van Dishoeck, E. F.**; Molecular Dynamics Simulations of CO2Formation in Interstellar Ices; *Journal of Physical Chemistry A*; 2013; **117**; 7064

Ardila, D. R., and 22 co-authors, including **Brown, A.**; Hot Gas Lines in T Tauri Stars; *ApJS*; 2013; **207**; 1

Argo, M. K., and 5 co-authors, including **Röttgering, H.**, **Miley, G.**; Probing the nature of compact ultrasteep spectrum radio sources with the e-EVN and e-MERLIN; *MNRAS*; 2013; **431**; L58

Asgekar, A., and 91 co-authors, including **Bell, M. E.**, **Bell, M. R.**, **de Jong, A.**, **Garrett, M. A.**, **Iacobelli, M.**, **Röttgering, H.**; LOFAR detections of low-frequency radio recombination lines towards Cassiopeia A; *A&A*; 2013; **551**; L11

Ashby, M. L. N., and 44 co-authors, including **Bouwens, R.**, **Labbé, I.**; SEDS: The Spitzer Extended Deep Survey. Survey Design, Photometry, and Deep IRAC Source Counts; *ApJ*; 2013; **769**; 80

Ashby, M. L. N., and 20 co-authors, including **Muzzin, A.**; The Spitzer South Pole Telescope Deep Field: Survey Design and Infrared Array Camera Catalogs; *ApJS*; 2013; **209**; 22

Ataiee, S., and 5 co-authors, including **Pinilla, P.**; Asymmetric transition disks: Vorticity or eccentricity?; *A&A*; 2013; **553**; L3

Aykutalp, A., and 3 co-authors, including **Meijerink, R.**; The Response of Metal-rich Gas to X-Ray Irradiation from a Massive Black Hole at High Redshift: Proof of Concept; *ApJ*; 2013; **771**; 50

Bahé, Y. M., and 3 co-authors, including **Balogh, M. L.**; Why does the environmental influence on group and cluster galaxies extend beyond the virial radius?; *MNRAS*; 2013; **430**; 3017

Balestra, I., and 43 co-authors, including **Bouwens, R.**, **Smit, R.**; CLASH-VLT: spectroscopic confirmation of a z = 6.11 quintuply lensed galaxy in the Frontier Fields cluster RXC J2248.7-4431; *A&A*; 2013; **559**; L9

Baneke, D.; Book Review: Between Rhetoric and Reality: Astronomical Practices at the Observatory of the Amsterdam Society 'Felix Meritis', 1786-1889; *Journal for the History of Astronomy*; 2013; **44**; 489

Bast, J. E., and 3 co-authors, including **van Dishoeck, E. F.**, **Tielens, A. G. G. M.**; Exploring organic chemistry in planet-forming zones; *A&A*; 2013; **551**; A118

Basu-Zych, A. R., and 14 co-authors, including **Bouwens, R. J.**; The X-Ray Star Formation Story as Told by Lyman Break Galaxies in the 4 Ms CDF-S; *ApJ*; 2013; **762**; 45

Bayet, E., and 24 co-authors, including **de Zeeuw, P. T.**; The ATLAS^{3D} project - XVI. Physical parameters and spectral line energy distributions of the molecular gas in gas-rich early-type galaxies; *MNRAS*; 2013; **432**; 1742

Beck, R., and 10 co-authors, including **Iacobelli, M.**; The LOFAR view of cosmic magnetism; *Astronomische Nachrichten*; 2013; **334**; 548

Bédorf, J., and **Portegies Zwart, S.**; The effect of many minor mergers on the size growth of compact quiescent galaxies; *MNRAS*; 2013; **431**; 767

Behroozi, P. S., and 5 co-authors, including **Muzzin, A.**; Using Cumulative Number Densities to Compare Galaxies across Cosmic Time; *ApJ*; 2013; **777**; L10

Beltrán, M. T., and 11 co-authors, including **Mottram, J. C.**; A Hi-GAL study of the high-mass star-forming region G29.96-0.02; *A&A*; 2013; **552**; A123

Benjamin, J., and 20 co-authors, including **Hoekstra, H.**, **Kuijken, K.**, **Semboloni, E.**; CFHTLenS tomographic weak lensing: quantifying accurate redshift distributions; *MNRAS*; 2013; **431**; 1547

Benz, A. O., and 4 co-authors, including **van Dishoeck, E. F.**; Neutral and Ionized Hydrides in Star-Forming Regions. Observations with Herschel/HIFI; *Journal of Physical Chemistry A*; 2013; **117**; 9840

Bergin, E. A., and 13 co-authors, including **van Dishoeck, E. F.**; An old disk still capable of forming a planetary system; *Nature*; 2013; **493**; 644

Bertin, M., and 9 co-authors, including **Fayolle, E. C.**, **Linnartz, H.**; Indirect Ultraviolet Photodesorption from CO:N_2 Binary Ices —an Efficient Grain-gas

Process; *ApJ*; 2013; **779**; 120

Bertone, S., and 2 co-authors, including **Schaye, J.**; How the diffuse Universe cools; *MNRAS*; 2013; **430**; 3292

Bezanson, R., and 5 co-authors, including **van de Sande, J.**, **Franx, M.**; Tight Correlations between Massive Galaxy Structural Properties and Dynamics: The Mass Fundamental Plane was in Place by z $\sim$ 2; *ApJ*; 2013; **779**; L21

Bezanson, R., and 4 co-authors, including **van de Sande, J.**, **Franx, M.**; Massive and Newly Dead: Discovery of a Significant Population of Galaxies with High-velocity Dispersions and Strong Balmer Lines at z $\sim$ 1.5 from Deep Keck Spectra and HST/WFC3 Imaging; *ApJ*; 2013; **764**; L8

Bílek, M., and 5 co-authors, including **Jílková, L.**; Testing MOND gravity in the shell galaxy NGC 3923; *A&A*; 2013; **559**; A110

Birkby, J. L., and 6 co-authors, including **Brogi, M.**, **Schwarz, H.**, **Snellen, I. A. G.**; Detection of water absorption in the day side atmosphere of HD 189733 b using ground-based high-resolution spectroscopy at 3.2 μm; *MNRAS*; 2013; **436**; L35

Birnstiel, T., and 2 co-authors, including **Pinilla, P.**; Lopsided dust rings in transition disks; *A&A*; 2013; **550**; L8

Bırzan, L., and 5 co-authors, including **Rafferty, D. A.**, **Röttgering, H. J. A.**; The duty cycle of the radio mode feedback; *Astronomische Nachrichten*; 2013; **334**; 390

Böhm, A., and 23 co-authors, including **Balogh, M.**; AGN host galaxies at redshift z $\sim$ 0.7: peculiar or not?; *A&A*; 2013; **549**; A46

Boland, W., and **Habing, H.**; Astronomy in the Netherlands; *Organizations, People and Strategies in Astronomy Vol. 2*; 2013; 145

Boogert, A. C. A., and 7 co-authors, including **Tielens, A. G. G. M.**, **van Dishoeck, E. F.**; Infrared Spectroscopic Survey of the Quiescent Medium of Nearby Clouds. I. Ice Formation and Grain Growth in Lupus; *ApJ*; 2013; **777**; 73

Boone, F., and 25 co-authors, including **van der Werf, P.**; An extended Herschel drop-out source in the center of AS1063: a normal dusty galaxy at z = 6.1 or SZ substructures?; *A&A*; 2013; **559**; L1

Booth, C. M., and **Schaye, J.**; The interaction between feedback from active galactic nuclei and supernovae; *Scientific Reports*; 2013;

Bösch, B., and 9 co-authors, including **Balogh, M.**; Tully-Fisher analysis of the multiple cluster system Abell 901/902; *A&A*; 2013; **554**; A97

Bösch, B., and 8 co-authors, including **Balogh, M.**; Ram pressure and dusty red galaxies - key factors in the evolution of the multiple cluster system Abell 901/902; *A&A*; 2013; **549**; A142

Bourke, S., and 3 co-authors, including **van Langevelde, H. J.**; An AIPS-based, distributed processing method for large radio interferometric datasets; *Experimental Astronomy*; 2013; **36**; 59

Bourne, N., and 23 co-authors, including **Rigby, E. E.**; Herschel-ATLAS: correlations between dust and gas in local submm-selected galaxies; *MNRAS*; 2013; **436**; 479

Bouwens, R. J., and 12 co-authors, including **Labbé, I.**, **Franx, M.**, **Smit, R.**; Photometric Constraints on the Redshift of z $\sim$ 10 Candidate UDFj-39546284 from Deeper WFC3/IR+ACS+IRAC Observations over the HUDF; *ApJ*; 2013; **765**; L16

Brammer, G. B., and 7 co-authors, including **Bouwens, R. J.**, **Labbé, I.**, **Franx, M.**; A Tentative Detection of an Emission Line at 1.6 μm for the z $\sim$ 12 Candidate UDFj-39546284; *ApJ*; 2013; **765**; L2

Brinchmann, J., and 5 co-authors; Estimating gas masses and dust-to-gas ratios from optical spectroscopy; *MNRAS*; 2013; **432**; 2112

Brogi, M., and 5 co-authors, including **Snellen, I. A. G.**, **Birkby, J. L.**; Detection of Molecular Absorption in the Dayside of Exoplanet 51 Pegasi b?; *ApJ*; 2013; **767**; 27

Brothers, T. C., and 2 co-authors, including **Holt, J. W.**; Orbital radar, imagery, and atmospheric modeling reveal an aeolian origin for Abalos Mensa, Mars; *Geophys. Res. Lett.*; 2013; **40**; 1334

Brown, J. M., and 5 co-authors, including **van Dishoeck, E. F.**; VLT-CRIRES Survey of Rovibrational CO Emission from Protoplanetary Disks; *ApJ*; 2013; **770**; 94

Bruni, G., and 6 co-authors, including **Holt, J.**; The parsec-scale structure of radio-loud broad absorption line quasars; *A&A*; 2013; **554**; A94

Bryan, S. E., and 5 co-authors, including **Schaye, J.**; The impact of baryons on the spins and shapes of dark matter haloes; *MNRAS*; 2013; **429**; 3316

Buchbender, C., and 15 co-authors, including **Israel, F. P.**, **van der Werf, P.**; Dense gas in M 33 (HerM33es); *A&A*; 2013; **549**; A17

Burton, M. G., and 17 co-authors, including **Walsh, A. J.**; The Mopra Southern Galactic Plane CO Survey; *PASA*; 2013; **30**; 44

Burtscher, L., and 11 co-authors, including **Jaffe, W.**, **Röttgering, H.**; A diversity of dusty AGN tori. Data release for the VLTI/MIDI AGN Large Program and first results for 23 galaxies; *A&A*; 2013; **558**; A149

Bussmann, R. S., and 48 co-authors, including **Smith, M.**, **van der Werf, P.**; Gravitational Lens Models Based on Submillimeter Array Imaging of Herschel-selected Strongly Lensed Sub-millimeter Galaxies at z > 1.5; *ApJ*; 2013; **779**; 25

Cacciato, M., and 4 co-authors; Cosmological constraints from a combination of galaxy clustering and lensing - III. Application to SDSS data; *MNRAS*; 2013; **430**; 767

Cai, Z.-Y., and 9 co-authors, including **Rigby, E.**; A Hybrid Model for the Evolution of Galaxies and Active Galactic Nuclei in the Infrared; *ApJ*; 2013; **768**; 21

Cappellari, M., and 23 co-authors, including **de Zeeuw, P. T.**; The ATLAS^{3D} project - XX. Mass-size and mass-σ distributions of early-type galaxies: bulge fraction drives kinematics, mass-to-light ratio, molecular gas fraction and stellar initial mass function; *MNRAS*; 2013; **432**; 1862

Cappellari, M., and 23 co-authors, including **de Zeeuw, P. T.**; The ATLAS^{3D} project - XV. Benchmark for early-type galaxies scaling relations from 260 dynamical models: mass-to-light ratio, dark matter, Fundamental Plane and Mass Plane; *MNRAS*; 2013; **432**; 1709

Carretti, E., and 8 co-authors, including **Haverkorn, M.**; Detection of a radio bridge in Abell 3667; *MNRAS*; 2013; **430**; 1414

Carretti, E., and 8 co-authors, including **Haverkorn, M.**; Giant magnetized outflows from the centre of the Milky Way; *Nature*; 2013; **493**; 66

Casetti-Dinescu, D. I., and 5 co-authors, including **Jílková, L.**; Space Velocities of Southern Globular Clusters. VII. NGC 6397, NGC 6626 (M28), and

NGC 6656 (M22); *AJ*; 2013; **146**; 33

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