Bachelor research projects
Cohort 2017-2018

1

TITLE	**Infrared spectroscopy of complex organic molecules embedded in interstellar ice**
SUPERVISOR(S)	Harold Linnartz, Jordy Bouwman, Jeroen Terwisscha van Scheltinga
CONTACT INFO	HL501/ linnartz@strw.leidenuniv.nl , HL516b/ bouwman@strw.leidenuniv.nl www.laboratory-astrophysics.eu
DESCRIPTION	The James Webb Space Telescope (launch spring 2019) will be able to search for interstellar ice features in the interstellar medium. Recent work has shown that so called COMs (complex organic molecules), the corner stones of the building blocks of life, are formed on icy grains. It has not been possible, however, to detect frozen COMs because of lacking laboratory data. The goal of this Ba project is to measure accurate IR spectra of one or two COMs embedded in an interstellar ice matrix for different conditions. The data will be compared with existing data files and used in the nearby future to search for the corresponding solid state signatures in JWST data.
NOTE	This project takes part in the Sackler Laboratory for Astrophysics. Some affinity with experimental lab work is required. Ideal for students A/N or N/A.

2

TITLE	**Molecular outflows from galaxies observed with Herschel**
SUPERVISOR(S)	Paul van der Werf
CONTACT INFO	Oort 565 / pvdwerf@strw.leidenuniv.nl www.strw.leidenuniv.nl/~pvdwerf/
DESCRIPTION	Outflows of molecular gas have recently been recognized to play a major role in star forming galaxies, expelling the fuel for star formation and halting the star formation process. The Herschel Space Observatory has revealed molecular outflows in observations of OH and many other molecules, including OH+. OH+ is a very powerful probe of outflow in high-redshift galaxies (observed with ALMA), but has the disadvantage that its abundance is very uncertain, so that it is difficult to calculate a mass outflow rate from OH+ outflow observations. In this project you will solve this by playing a trick: you will analyse the outflow data for ~10 galaxies where the outflow has been detected in both OH and OH+. You will then "calibrate" the OH+ outflow rate using the OH data, which will allow computation of total molecular gas mass outflow rates, since the OH abundance is fairly stable and well known.

3

TITLE	**Trapping and desorption of noble gases in amorphous ices**
SUPERVISOR(S)	Harold Linnartz, Ewine van Dishoeck, Jeroen Terwisscha van Scheltinga
CONTACT INFO	HL501 / linnartz@strw.leidenuniv.nl , HL505 / ewine@strw.leidenuniv.nl , www.laboratory-astrophysics.eu

DESCRIPTION	Noble gases such as Argon, Krypton and Xenon are key diagnostics in studies of the origin of our solar system. They are highly volatile gases, so their detection in cometary samples implies that these species have been trapped inside ices and preserved over the lifetime of our solar system. Recently, the ROSINA mass spectrometer on the Rosetta mission has detected all of these noble gases (and their various isotopic forms) in the coma of comet 67P. These data have been used to make rather strong conclusions on the birth environment of our solar system, such as the temperature of the comet forming region (Mousis et al. 2016). All of these conclusions are based on laboratory data of rather poor quality, however, especially for amorphous ices. The main goal of this MSc project is to use the state-of-the-art equipment in the Sackler laboratory for Astrophysics to measure the trapping and desorption of Argon, CO and N2 in amorphous water ice for various deposition rates, temperatures, porosities and desorption rates. These data will then feed into models of the ROSINA team members to re-assess the conclusions.
NOTE	Bar-Nun et al. 2007, Icarus 190, 655 Collings et al. 2004, MNRAS 354, 1133 Mousis et al. 2016, ApJ 819, L33, and references cited

4

TITLE	**Particle acceleration in merging galaxy clusters**
SUPERVISOR(S)	Timothy Shimwell, Reinout van Weeren
CONTACT INFO	0454 / shimwell@strw.leidenuniv.nl , 0465 / rvanweeren@strw.leidenuniv.nl
DESCRIPTION	Shocks and turbulence that are introduced into the intra cluster medium by energetic merging events produce observable radio emission. The Netherlands based Low Frequency Array (LOFAR) is mapping this emission in detail but to understand the particle acceleration mechanisms we need to combine LOFAR images with higher frequency maps. In this project we aim to analyse archival VLA data to interpret radio emission from merging galaxy clusters that host some of the most prominent shocks.
NOTE	Experience programming in python is desirable.

5

TITLE	**The Origin of Interstellar Object A/2017 U1**
SUPERVISOR(S)	Anthony Brown
CONTACT INFO	Oort536 / brown@strw.leidenuniv.nl
DESCRIPTION	Recently a minor solar system body, named A/2017 U1, was discovered and it was confirmed to be on a hyperbolic orbit, suggesting that it is of interstellar origin. The goal of this project is to investigate the possible origin of this solar system intruder through a survey of the literature, and by searching for stars in the Gaia catalogue from which this object could have originated.
NOTE	This project requires integrating the orbits of A/2017 U1 and nearby stars to investigate if they were in the same physical location at some time in the past.

6	
TITLE	**What does Gaia see in Andromeda?**
SUPERVISOR(S)	Anthony Brown
CONTACT INFO	Oort536 / brown@strw.leidenuniv.nl
DESCRIPTION	Although the Gaia mission is designed primarily to observe stars in our own galaxy, it will observe any point source brighter than magnitude ~20, including in other galaxies. The goal of this project is to explore what Gaia is actually detecting as sources in the Andromeda (M31) galaxy. Is it observing individual stars, clusters, star forming regions? This inventory is a first step to understanding what scientific results can be obtained from a study of M31 with Gaia (for example, can we measure the rotation of this galaxy at 2 million light years distance?).
NOTE	This will involve a cross-matching between the Gaia catalogue and other observations, primarily images from the Hubble Space Telescope. The ESA-sky tool (http://sky.esa.int/) is well suited for this.

7	
TITLE	**Three-wave shearing interferometer for wavefront sensing using liquid crystal phase plates**
SUPERVISOR(S)	Emiel Por
CONTACT INFO	por@strw.leidenuniv.nl
DESCRIPTION	Shearing interferometry has always been seen as an extremely simple but effective way for measuring of aberrations in an optical system. Conventionally only two pupils are used for this interferometer requiring two measurements (one horizontal and one vertical). Only recently the concept of using more that two interfering pupils was proposed requiring only a single measurement, although the implementation of these devices is inherently monochromatic. However, it turns out that using liquid crystal phase plates we can make this interferometer work in broadband light. The student(s) will implement a prototype using liquid crystal phase plates in the optical laboratory and perform simulations and lab measurements validating this technique.
NOTE	This project will include modelling and lab work.

8	
TITLE	**Integral Field Spectrograph for broadband speckle control on a multi-core single-mode fiber-array**
SUPERVISOR(S)	Emiel Por, Sebastiaan Haffert
CONTACT INFO	por@strw.leidenuniv.nl , haffert@strw.leidenuniv.nl
DESCRIPTION	A single-mode fiber only allows propagation of a single optical mode. Last year we introduced the SCAR coronagraph, which uses this property to block starlight while

	transmitting planet light. First measurements were performed with only one single-mode fiber using a monochromatic light source, yielding excellent performance in agreement with models. The performance of the SCAR coronagraph is however untested using multiple fibers and broadband light. We recently acquired an 11x11 multi-core single-mode fiber, which allows for testing the SCAR coronagraph and speckle control algorithms in broadband light. The student(s) will design and build an integral field spectrograph for this fiber and perform initial experiments on its performance with the SCAR coronagraph.
NOTE	This project will include modelling and lab work.

9	
TITLE	**Tomographic reconstruction of the inner stellar disk with high-resolution spectro-polarimetry**
SUPERVISOR(S)	Sebastiaan Haffert, Jos de Boer
CONTACT INFO	haffert@strw.leidenuniv.nl , deboer@strw.leidenuniv.nl
DESCRIPTION	The inner region of stellar disks are difficult to resolve from their host star due to the small angular separation. Because most inner disk regions are unresolved it is difficult to measure the parameters of this region. These parameters are important for disk evolution and disk/star interaction.High-resolution spectroscopy will allow us to resolve the disk from the star because the star and disk will have a different radial velocity. But because the star is very bright compared to the stellar disk it will be difficult to see the disk in the data. Polarimetry can be used to filter out the star because it is unpolarized while the disk is polarized. Combining the two techniques in high-resolution spectro-polarimetry will allows us to probe the inner disk region through tomography. In this project the student(s) will develop a model to test if we could use high-resolution spectro-polarimetry to resolve features from the inner disk region.
NOTE	This project is observational and modelling based.

10	
TITLE	**Non-linear wavefront reconstruction for the generalized optical differentiation wavefront sensor**
SUPERVISOR(S)	Sebastiaan Haffert
CONTACT INFO	haffert@strw.leidenuniv.nl
DESCRIPTION	Due to the turbulence in the air telescopes do not reach their resolution limit. With adaptive optics we can correct for the turbulence and reach the diffraction limit. To correct the turbulence a wavefront sensor is necessary to measure the wavefront errors. The g-ODWFS is a new type of wavefront sensor for which the concept was recently developed in Leiden. A prototype has been built and verified in the lab. The g-ODWFS has an intrinsic non-linear response. The student(s) will develop a non-linear reconstruction algorithm. This will allow for a faster response and more precise

	measurements. This non-linear reconstruction algorithm will implemented in the lab on our adaptive optics system.
NOTE	This project will include modelling and lab work.

11	
TITLE	**Sub-diffraction limit imaging through Spatial Mode Demultiplexing (SPADE)**
SUPERVISOR(S)	Sebastiaan Haffert, Emiel Por
CONTACT INFO	haffert@strw.leidenuniv.nl , por@strw.leidenuniv.nl
DESCRIPTION	From the Rayleigh criterion follows the resolving power for telescope. This criterion puts a strong constraint on angular separation between two that can still be resolved. For smaller separations the amount of photons that are necessary to resolve two sources increases exponentially. Recent work has shown that if the phase information is used, the necessary amount of photons stays constant as function of angular separation. This allows for sub-diffraction limit imaging of incoherent sources. The phase information can be encoded through spatial mode demultiplexing (SPADE). The student(s) will use a holographic SPADE that has been designed and manufactured to investigated the stability of the demultiplexing both in simulation and in the lab.
NOTE	This project will include modelling and lab work.

12	
TITLE	**A concept for a dual-star photometric unit to enable exoplanet characterization with HARPS3**
SUPERVISOR(S)	Patrick Dorval, Frans Snik
CONTACT INFO	dorval@strw.leidenuniv.nl , snik@strw.leidenuniv.nl
DESCRIPTION	An international consortium is currently building a third version of the famous HARPS instrument, that will detect Earth-like planets through a very targeted 10-yr radial velocity survey at the Isaac Newton Telescope (INT). This survey aims to reach a radial velocity precision of 10 cm/s. A high resolution (R~115,000) fiber-fed spectrograph like HARPS can generally not be used for accurate spectrophotometric observations of transiting exoplanets, but additional photometric data can make this a reality. Within the Dutch work-package (the Cassegrain Unit of HARPS3), an idea was generated to upgrade this Cassegrain unit such that two stars can be observed at the same time to obtain a photometric reference. This implementation will enable unique observations to characterize exoplanet atmospheres. The student will turn this (somewhat crazy) idea into a concrete instrument design, minimizing impact to the current work-package and installation on the INT, and perform simulations of sky coverage and spectrophotometric performance.
NOTE	This project will cover a wide range of aspects (from simulation to instrument design), and will involve collaboration with Jean-Michel Desert in Amsterdam and with the NOVA opt/IR group in Dwingeloo.

13	
TITLE	**Crowded-field observations using an Apodizing Phase Plate on ELT/MICADO**
SUPERVISOR(S)	Frans Snik, Remko Stuik, Emiel Por
CONTACT INFO	snik@strw.leidenuniv.nl , stuik@strw.leidenuniv.nl , por@strw.leidenuniv.nl
DESCRIPTION	MICADO is the first-light imaging instrument for the ELT. One of its science cases is to provide accurate photometry and astrometry of crowded fields, at the extreme spatial resolution enabled by the 39-m telescope. In Leiden, we are developing pupil-plane optics to manipulate the PSF to enable high-contrast imaging of exoplanets. In this project, the student will apply such optics to crowded-field observations, for the first time. We will develop a pupil phase pattern that will suppress many Airy rings in the PSF of every source in the field, such that only a PSF core and a single diffraction ring are present, and the remainder of the diffraction structure is absent within the field of view. This phase patterned is implemented into a comprehensive model of MICADO (incl. AO performance and thermal background) to simulate the expected images of crowded fields. The student will then apply photometric and astrometric fitting on faint sources close to bright sources to assess the performance gain delivered by this novel approach.
NOTE	This project involves collaboration with MICADO team members in Groningen and Nijmegen.

14	
TITLE	**Resolved spectroscopy of planet forming disks with SPHERE/IFS**
SUPERVISOR(S)	Christian Ginski, Jos de Boer, Schuyler Wolf
CONTACT INFO	ginski@strw.leidenuniv.nl , deboer@strw.leidenuniv.nl , wolf@strw.leidenuniv.nl
DESCRIPTION	A large amount of unpublished integral field spectroscopy data exists for several planet forming circumstellar disks. The student will be asked to develop a reduction pipeline for SPHERE/IFS data. Once the basic data reduction is achieved advanced methods of removal of the bright primary star from the data will be discussed. The goal of the project is to extract reliable spectral information for a one or several planet forming disks. Such data can then be used by the senior researchers to determine dust grain properties, which in turn will enable a better understanding of ongoing planet formation in these disks.
NOTE	This project relies heavily on coding, ideally in Python. Meaningful results will be either part of upcoming SPHERE proposals or a future publication.

15	
TITLE	**Understanding ring systems - radiative transfer modeling of multiple ringed circumstellar disks**

SUPERVISOR(S)	Christian Ginski, Jos de Boer
CONTACT INFO	ginski@strw.leidenuniv.nl , deboer@strw.leidenuniv.nl
DESCRIPTION	The past 5 years have revolutionized our view of young planet forming disks around nearby stars. With the completion of ALMA and SPHERE, two powerful instruments are now available to image these disks in near-infrared scattered light, as well as mm-emission. However, the potential of combining the data from both instruments to gain a more detailed understanding is so far largely unused. The student will carry out radiative transfer modeling (using an existing code) of a multiple ringed disk that has been observed with both SPHERE and ALMA. Main tasks will be to develop a Python framework in which the radiative transfer code can be executed to efficiently explore the large parameter space. Particular emphasize will lie on the question on how multiple ringed sub-structures can form in young disks and whether or not they are connected to planet formation.
NOTE	Project will be coding intensive and good knowledge of Python is strongly preferred.

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TITLE	**Finding exo-planets in (vAPP) coronagraphic data**
SUPERVISOR(S)	Jos de Boer, Alex Bohn, Frans Snik
CONTACT INFO	deboer@strw.leidenuniv.nl , bohn@strw.leidenuniv.nl , snik@strw.leidenuniv.nl
DESCRIPTION	In our quest for the direct detection of exoplanets, we have recently installed a state of the art coronagraph called the vector Apodizing Phase Plate (vAPP) on multiple of the world's best high-contrast imagers. This versatile coronagraph, developed by our group in Leiden, reshapes the stellar speckle halo to create a "dark-hole" at the region where we expect to find a planet. The student will develop algorithms to inject synthetic planets into on-sky data taken with the vAPP. To determine the photometry and astrometry (which are key parameters to determine the mass and orbit) of the planet, the student will test various data reduction algorithms such as classical Angular Differential Imaging and Principle Component Analysis. Varying the intrinsic brightness of the planet will allow us to retrieve detection limits. This work will be an important preparation for upcoming observations and future upgrades of additional high-contrast imagers with vAPP coronagraphs.
NOTE	During this project, the student will learn the basic data-reduction techniques that can be applied for the data-reduction of almost any high-contrast imager.

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TITLE	**Pathfinder to characterize the grains that will form exoplanets**
SUPERVISOR(S)	Jos de Boer, Christian Ginski, Rob van Holstein
CONTACT INFO	deboer@strw.leidenuniv.nl ,inski@strw.leidenuniv.nl vanholstein@strw.leidenuniv.nl
DESCRIPTION	Dust grains in planet forming (or protoplanetary) disks grow with time to form

	pebbles, comets and eventually planets. We are working with VLT/SPHERE, the state of the art high-contrast imager at the Very Large Telescope in Chile to image protoplanetary disks in polarized (= scattered) light. With current techniques we can create beautiful images of protoplanetary disks from which we can retrieve the large scale disk morphology. However, retrieving the properties of the small dust grains (crucial information for our understanding of grain growth) from the polarized intensity images is not possible. To do so requires an alternative treatment of the same dataset to obtain the disks' total intensity images. Combining polarized and total intensity images brings us the strong constraints necessary to determine the particle properties with our disk models. In december 2017, we will test a new observing mode with VLT/SPHERE that will yield data more suitable for dust characterization. The student(s) will reduce this new dataset by subtracting a reference star (without disk) from the science star (with disk), which will yield a total intensity image of the disk. To quantify the improvement yielded by the new observing mode, the student will apply a similar reduction on archival data.
NOTE	Prior knowledge of polarization/polarimetry is not necessary. During this project, the student will learn the basic data-reduction techniques that can be applied for the data-reduction of almost any high-contrast imager.

18	
TITLE	**Measuring polarization aberrations in the lab**
SUPERVISOR(S)	Rob van Holstein, Frans Snik
CONTACT INFO	vanholstein@strw.leidenuniv.nl , snik@strw.leidenuniv.nl
DESCRIPTION	The direct detection of exoplanets is currently only feasible for young (= hot) self-luminous giant exoplanets. To detect and characterize for the first time old (= cold) giant planets in reflected visible light, the high-contrast imaging polarimeter SPHERE-ZIMPOL is recently installed at the Very Large Telescope (VLT). The contrast ZIMPOL achieves is limited by polarization aberrations, i.e. polarization-dependent deviations to the ideal point spread function (PSF). We are developing a model describing these polarization aberrations to improve the data-reduction, the observing strategies and the instrument itself, with the goal of detecting these old planets in reflected light. In this project we will validate the model predictions for the two most important optical components: a silver coated mirror and a crystal half-wave plate. This work comprises a complete end-to-end experimental project: the student will design and build a test setup in the lab, perform the experiments, interpret the results and assess where the model needs improvements. The validated model will not only be applied to SPHERE-ZIMPOL, but will also be used to improve the performance of other existing high-contrast imagers (e.g. SCExAO) and to design the future planet characterization instrument EPICS on the E-ELT.
NOTE	Prior knowledge of polarization/polarimetry is not necessary. During this project, the student will learn the basic data-reduction techniques that can be applied for the data-reduction of almost any high-contrast imager.

19	
TITLE	**Characterizing the disc around the star BP Psc**
SUPERVISOR(S)	Lizette Guzman-Ramirez, Jos de Boer, Michiel Hogerheijde
CONTACT INFO	HL1122 / guzmanl@strw.leidenuniv.nl , HL1127/ deboer@strw.leidenuniv.nl , michiel@strw.leidenuniv.nl
DESCRIPTION	Planet formation is generally considered to occur in circumstellar discs around young stars. However, discs are known to exist around stars at later stages of their life when the star loses material on its way to the Asymptotic Giant Branch. We currently don't know whether these discs around evolved stars are capable of planet formation because the characteristics of the discs are not as well known as for those around young stars. The star BP Psc was first believed to be a young star. However, with more observations, it is now thought that the star has left the main sequence and is a lot older than thought. BP PSc has been observed with telescopes from the optical, infrared, and all the way to the submillimeter. Recently, ALMA observed this star in thermal emission of cold dust and emission lines of CO. The goal of the project is to calibrate, image, and analyse these data. The students will derive the amount of mass in the disc around the star and in material associated with the jet driven by the star; they will analyse the gas kinematcs; and they will make a simple geometric model for the object to explain the observations. This will help us understand if planets could form in the extreme environment around evolved stars.

20	
TITLE	**The UV properties of faint star-forming galaxies seen with MUSE**
SUPERVISOR(S)	Jarle Brinchmann
CONTACT INFO	0455 / jarle@strw.leidenuniv.nl
DESCRIPTION	The MUSE integral field spectrograph has been very efficient at obtaining spectra of extremely faint galaxies. The spectra of the galaxies call tell us about the amount of stars they form and in principle we should also know this from their rest-UV light which traces massive stars. That is not always the case. The main focus of this project is to study the efficiency of production of ionising photons in moderately distant ($z \sim 0.5$-1), but extreme, galaxies and how this relates to the same measurements at high redshifts.

21	
TITLE	**Improving photometric redshifts of faint galaxies using machine learning approaches**
SUPERVISOR(S)	Jarle Brinchmann
CONTACT INFO	0455 / jarle@strw.leidenuniv.nl

DESCRIPTION	When no spectra are available, the best way to determine the distance to galaxies is to measure their photometric redshifts - these are determined from photometric measurements only and are the base upon which many current and future rely. Recently, we have published the first set of systematic measurements of photometric redshifts of very faint (R>26) galaxies and found systematic biases. In this project the student will attempt to improve the photometric redshift measurements using machine learning techniques, as well as explore new ways to incorporate the effect of absorption by the intergalactic medium.
NOTE	This project will have a heavy component of coding and some knowledge of statistics/data mining is highly desirable.

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TITLE	**Improving photometric redshifts of faint galaxies using machine learning approaches**
SUPERVISOR(S)	Jarle Brinchmann
CONTACT INFO	0455/ jarle@strw.leidenuniv.nl
DESCRIPTION	When no spectra are available, the best way to determine the distance to galaxies is to measure their photometric redshifts - these are determined from photometric measurements only and are the base upon which many current and future rely. Recently, we have published the first set of systematic measurements of photometric redshifts of very faint (R>26) galaxies and found systematic biases. In this project the student will attempt to improve the photometric redshift measurements using machine learning techniques, as well as explore new ways to incorporate the effect of absorption by the intergalactic medium.
NOTE	This project will have a heavy component of coding and some knowledge of statistics/data mining is highly desirable.

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TITLE	**Long-term variability in the Multi-site All-Sky CAmeRA data**
SUPERVISOR(S)	Ignas Snellen, Jan Lub
CONTACT INFO	snellen@strw.leidenuniv.nl, lub@strw.leidenuniv.nl
DESCRIPTION	This project is to search for long-term variability properties in Cepheids and possible other variable stars in the MASCARA data.

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TITLE	**How much we should trust ALMA?**
SUPERVISOR(S)	Jacqueline Hodge, Matus Rybak

CONTACT INFO	Oort 458/ hodge@strw.leidenuniv.nl , Oort 464/ mrybak@strw.leidenuniv.nl
DESCRIPTION	Large radio-interferometers, such as ALMA, do not simply take pictures of the sky. Instead, the signal measured by 40+ ALMA antennas has to be combined to obtain a synthesised image. But how reliable are images of complex sources, e.g. as spiral galaxies? This project will look at how much we can trust inferred source properties - size, brightness, complex structure - obtained from ALMA observations.

25	
TITLE	**Telling mergers from disk galaxies with ALMA**
SUPERVISOR(S)	Jacqueline Hodge, Matus Rybak
CONTACT INFO	Oort 458 / hodge@strw.leidenuniv.nl , Oort 464 / mrybak@strw.leidenuniv.nl
DESCRIPTION	ALMA, a new large array of mm-wave telescopes, is now focusing on a large number of redshift>2 galaxies. At such a distance, even with the full power of ALMA, the images of galaxies are often too faint and compact to be properly resolved. Often, even distinguishing a large disk galaxy from a pair of colliding ones is a difficult task. This explorative project will simulate ALMA observations of well-known nearby galaxies if they were at high redshift, and investigate how well can we classify these galaxies from ALMA data.

26	
TITLE	**Hidden massive black holes in star forming galaxies**
SUPERVISOR(S)	Jacqueline Hodge, Gabriela Calistro Rivera
CONTACT INFO	Oort 458/ hodge@strw.leidenuniv.nl , Oort 551 / calistro@strw.leidenuniv.nl
DESCRIPTION	While all galaxies host black holes in their centers, in some cases these black holes are accreting matter producing a luminous phenomenon known as active galactic nuclei 'AGN'. In this project the student will investigate the contribution of AGN to the total emission of some of the most luminous galaxies in the early Universe. Based on multiwavelength photometric observations and using a fitting tool written in Python (AGNfitter), the student will analyse the galaxies' spectral energy distributions (SED) to infer the accreting black hole's component.
NOTE	Python knowledge is recommended.

27	
TITLE	**Interferometry & computers**
SUPERVISOR(S)	Walter Jaffe
CONTACT INFO	HL516c/ jaff@strw
DESCRIPTION	ESO's Very Large Interferometric Telescope consists of four fixed and four movable

	telescopes that can be combined to project super-high resolution images with the equivalent of a 200 meter telescopes. However, we need to decide which of the thousands of possible combinations of the movable telescope yield the best images. The project is to simulate observations of various sources with many, if no all, of the possible telescope positions to see which ones give the best results.

28	
TITLE	**Photoinduced dissociation of Complex Organic Molecules in the ISM**
SUPERVISOR(S)	Jordy Bouwman & Harold Linnartz
CONTACT INFO	HL516b / bouwman@strw.leidenuniv.nl HL501 / linnartz@strw.leidenuniv.nl http://home.strw.leidenuniv.nl/~bouwman/ , www.laboratory-astrophysics.eu
DESCRIPTION	Complex organic molecules (COMs) are formed through chemical reactions on ice covered grain surfaces that surround a protostar. As the COMs are released in the gas phase, they undergo transformations induced by the UV radiation from the central star. The formed species participate in the gas phase reaction network that eventually results in the formation of the building blocks of life. The goal of this project is to characterize how COMs dissociate by employing quantum chemical computations. The resulting data can be used for the interpret.
NOTE	The student will be trained in computational chemistry. Interest in and affinity with understanding how molecules behave is needed.

29	
TITLE	**Quasar + radio galaxy unification**
SUPERVISOR(S)	Huub Rottgering
CONTACT INFO	rottgering@strw.leidenuniv.nl
DESCRIPTION	Quasars and radio galaxies are different beasts of active galactic nuclei. One of the ideas is that these two classes of objects can be unified assuming we observe these objects along different lines of sight. With the new deep and large LOFAR maps we can test this idea better than ever.