SANTANDER
INTERNATIONAL SUMMER SCHOOLS FOR DOCTORAL STUDENTS

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

REACHING THE LIMITS OF THE SKY
ASTRONOMICAL INSTRUMENTATION IN THE 21ST CENTURY

PROGRAMME BOOK

NOVEMBER 17 TO 28, 2014
HEIDELBERG CENTER FOR LATIN AMERICA (HCLA), SANTIAGO DE CHILE

COOPERATION PARTNERS

Pontificia Universidad Católica de Chile (PUC)
Planetarium – Universidad de Santiago de Chile (USACH)
ESO Vitacura Office
ESO Observatory Cerro Paranal

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CONTENT

Santander UNIVERSIDADES

Universität Heidelberg,
University Square

UNIVERSITÄT HEIDELBERG

Heidelberg University, founded in 1386, is Germany's oldest university and one of the strongest research universities in Europe. The successes in both rounds of the Excellence Initiative of the German federal and state governments and in international rankings prove its leading role in the scientific community. In terms of educating students and promoting promising young academics, Heidelberg relies on research-based teaching and a well-structured training for doctoral candidates.

Heidelberg University is a comprehensive university with the full spectrum of subjects including medicine. It aims to strengthen the individual disciplines, to further interdisciplinary cooperation and to make research results usable for society and industry.

Heidelberg also draws its strength from its cooperation with local non-university research institutions. In addition, the university is tied into a worldwide network of research and teaching collaborations which give evidence of its marked global interconnectedness.

International Profile
Heidelberg University is tied into a worldwide network of research and teaching collaborations. Exchange programmes have been established with more than 400 universities worldwide. Heidelberg's marked global interconnectedness is also evidenced by its 19 university partnerships and three International Research Training Groups as well as its membership in European networks such as the League of European Research Universities (LERU) and the Coimbra Group.

A myriad of research and teaching collaborations are also established at the faculty, institute and chair levels. Additionally, Heidelberg has a satellite campus in Latin America as well as liaison offices in North America and Asia. The university also offers courses in Eastern Europe.

Heidelberg's international prominence is reflected in its student population: approximately 20 percent of Heidelberg's students and a third of the enrolled doctoral candidates come from abroad. According to a DAAD survey, Heidelberg is the favoured German university for international doctoral candidates.

SANTANDER UNIVERSIDADES

Santander, Committed to Higher Education
The university plays a fundamental role in the knowledge society. It acts as a guide towards an innovative society, contributing to economic and social change and supporting scientific and technological progress.

Through its Santander Universities Global Division, Banco Santander has collaborated with universities for more than 16 years on a unique global initiative which distinguishes it from other national and international banks and financial institutions.

In 1996, Emilio Botín, Chairman of Santander, decided that the bank should be useful to the societies in which it operates. With the conviction that the university is a vital cornerstone of development and progress, it was decided that Santander's long term commitment would be materialised through creating a programme to help the academic world in its role as a guardian of knowledge and a key agent in achieving progress in terms of economic competitiveness and social wellbeing.

Santander Universities maintains a stable alliance with more than 1,040 universities from America, Asia and Europe.

In 2011, through Santander Universities, Banco Santander contributed over 110 million euros to cooperation projects with universities of America, Asia and Europe.

More than 2,130 professionals coordinate and manage Santander's commitment to higher education through Santander Universities Global Division. In the words of Emilio Botín, Chairman of Santander: »Increased employment and welfare provision is based on education, research and effort.«

Academic institutions are receiving support from Santander for the development of academic initiatives relating to scholarships, mobility grants, research programmes, university-enterprise relations, new technologies.


BADEN - WÜRTTEMBERG
HEIDELBERG CENTER PARA AMERICA LATINA

PROGRAMME OVERVIEW

MON 17	TUE 18	WED 19	THU 20	FRI 21	SAT 22	SUN 23	MON 24	TUE 25	WED 26	THU 27	FRI 28	SA 29
	9:30-13:00 h	9:30-13:00 h	9:30-13:00 h	6:00-1:00 h HCLA	10:00-23:00 Antofagasta	10:30-21:30 h HCLA	9:30-13:00 h	9:30-13:00 h	9:30-13:00 h	9:00-13:00 h ESO Vitacura Office	9:00-12:30 h ESO Vitacura Office	Departure participants
Arrival participants	**Lectures** Kaufer, Vanzi, Gredel	**Lectures** Herbst, Girard, Mawet	**Lectures** Chauvin, Girard	**Student excursion to Paranal**	**Student excursion to Paranal**	Excursion to Cajón del Maipo	**Lectures** van Belle, Tristram, Herbst	**Lectures** Glindemann, Quirrenbach, van Belle	**Lectures** Glindemann, Quirrenbach, Merand	**Symposium** Henning, Dullemond	**Symposium** Fridlund, Jordán	
			Lunch						Lunch			
13:00-16:00 h HCLA Foyer **Welcome Desk & Poster Setup**	14:30-18:00 h **Lectures** Herbst, Chauvin, Mawet	14:30-17:00 h **Lectures** Béchet, Herbst	14:30-18:00 h **Lectures** Guesalaga, Gredel, Angeloni				14:30-18:00 h **Lectures** Glindemann, Quirrenbach, van Belle	14:30-18:00 h **Lectures** Merand, Pfuhl	14:30-17:00 h **Lectures** Merand, Pfuhl	14:00-17:30 h **Symposium** Catling, Fridlund	13:30-17:00 h **Symposium** Guedel	
16:00-17:30 h Welcome Session								**Career Seminar** Henning, Infante				
			Dinner						Dinner			
18:00 h HCLA Welcome Dinner	20:00-22:00 h **Poster Session**	19:00-20:30 h Planetarium **Public Lecture** Infante				Dinner & Wine Tasting			19:00-20:30 h Planetarium **Public Lecture** Henning		19:00 h HCLA Farewell Dinner	

A look back to the ESO Ultra HD Expedition's time at Paranal – the stars within their grasp.

DETAILED PROGRAMME

MONDAY, NOVEMBER 17, 2014

Arrival participants

13:00 – 15:00 Welcome Desk at HCLA
15:00 – 16:00 Poster Setup
15:30 – 16:00 *Coffee break*
16:00 – 18:00 WELCOME SESSION
Thomas Henning, Leopoldo Infante, Walter Eckel, Isabel Eisenmann
18:00 – 20:00 **Welcome Dinner / Barbecue,** HCLA

TUESDAY, NOVEMBER 18, 2014

OVERVIEWS; ADAPTIVE OPTICS I: FUNDAMENTALS; WAVE PROPAGATION

09:30 – 18:00 LECTURES
09:30 – 11:30 **Andreas Kaufer,** European Southern Observatory (ESO): »ESO and its instrumentation programme«
Leonardo Vanzi, Pontificia Universidad Católica de Chile: »Astro-Engineering at the PUC«
11:30 – 11:45 *Coffee break*
11:45 – 13:00 **Roland Gredel,** Max-Planck-Institut für Astronomie: »The E-ELT and its instrumentation«
13:00 – 14:30 *Lunch*
14:30 – 16:30 **Tom Herbst,** Max-Planck Institut für Astronomie: »Infrared astrophysics: natural limits to infrared observing«
Gaël Chauvin, Laboratoire d'Astrophysique de l'Observatoire de Grenoble:
»Fundamentals of adaptive optics: description of wavefronts«
16:30 – 16:45 *Coffee break*
16:45 – 18:00 **Dimitri Mawet,** European Southern Observatory (ESO): »Wavefront correction: deformable mirrors«
18:00 – 19:00 *Dinner*
20:00 – 22:00 POSTER SESSION

WEDNESDAY, NOVEMBER 19, 2014

ADAPTIVE OPTICS II: WAVEFRONT SENSING, LGS, VLT & LBT INSTRUMENTATION

09:30 – 17:00 **LECTURES**

09:30 – 11:30 **Tom Herbst,** Max-Planck Institut für Astronomie: »Wavefront sensing & reconstruction«
Julien Girard, European Southern Observatory (ESO): »The AO – Zoo – GLAO, MCAO, XAO, LTAO ...«
11:30 – 11:45 *Coffee break*
11:45 – 13:00 **Dimitri Mawet,** European Southern Observatory (ESO): »The VLT Exoplanet imager Sphere«
13:00 – 14:30 *Lunch*
14:30 – 15:45 **Clémentine Béchet,** Pontificia Universidad Católica de Chile:
»Requirements for tomographic adaptive optics systems«
15:45 – 16:00 *Coffee break*
16:00 – 17:00 **Tom Herbst,** Max-Planck Institut für Astronomie:
»The LBT Linc-Nirvana multi-conjugate adaptive optics system«
17:00 – 18:00 *Dinner*
18:00 *Transfer from HCLA to Planetarium*
19:00 – 20:30 **PUBLIC LECTURE,** Planetarium
Leopoldo Infante, Pontificia Universidad Católica:
»Observing the past: from photons to data product to science«
20:30 *Transfer from Planetarium to HCLA*

THURSDAY, NOVEMBER 20, 2014

ADAPTIVE OPTICS III: WAVEFRONT CORRECTION, ELT INSTRUMENTATION

09:30 – 18:00 **LECTURES**

09:30 – 11:30 **Gaël Chauvin,** Laboratoire d'Astrophysique de l'Observatoire de Grenoble:
»Coronography and angular differential imaging; Imaging of extrasolar planets«
11:30 – 11:45 *Coffee break*
11:45 – 13:00 **Julien Girard,** European Southern Observatory (ESO):
»The VLT adaptive optics system; The VLT laser guide star«
13:00 – 14:30 *Lunch*
14:30 – 16:30 **Andrés Guesalaga,** Pontificia Universidad Católica de Chile: »Wide field adaptive optics«
Roland Gredel, Max-Planck-Institut für Astronomie: »Adaptive Optics with Luci 1&2 at the LBT«
16:30 – 16:45 *Coffee break*
16:45 – 18:00 **Rodolfo Angeloni,** GEMINI Observatory: »The Bombolo Instrument«
18:00 – 19:00 *Dinner*

FRIDAY, NOVEMBER 21, 2014

06:00 – 01:00 Student excursion to ESO Observatory Cerro Paranal / Antofagasta
Weather-proof, warm clothing is recommended! For the hotel check-in at Antofagasta: Please bring your passport and (for non-Chileans) the entry form you received at the airport on your arrival in Chile!

06:00 – 07:00 *Bus trip from HCLA to Santiago Airport*
08:25 – 10:25 *Flight from Santiago to Antofagasta*
11:00 – 13:00 *Bus trip from Antofagasta Airport to Cerro Paranal*
13:15 – 14:30 *Lunch*
14:30 – 17:30 Visit of Observatory
17:30 – 18:30 *Dinner*
19:00 Telescope Opening
20:17 Sunset
20:30 – 23:00 Visit of Control Room/Observations
23:00 – 01:00 *Bus trip from Cerro Paranal to hotel (Hotel Terrado Suites, Baquedano 015, Antofagasta)*

SATURDAY, NOVEMBER 22, 2014

10:00 – 23:00 Student excursion to Cerro Paranal / Antofagasta
Don't forget beach wear and a towel! (Depending on weather conditions)

morning hotel check-out until 12:00 a.m.
Free time / beach time at Antofagasta – *please get yourself a lunch!*
14:00 – 15:00 *Bus trip to La Portada*
15:00 – 17:00 Free time at La Portada
17:00 – 18:00 *Dinner*
18:00 – 18:30 *Bus trip from La Portada to Antofagasta Airport*
19:50 – 21:45 *Flight from Antofagasta to Santiago*
22:30 – 23:00 *Bus trip from Santiago Airport to HCLA*

SUNDAY, NOVEMBER 23, 2014

10:30 – 21:30 Excursion to canyon Cajón del Maipo with Snack Lunch, Dinner and Wine tasting
Weather-proof clothing, sun blocker and adequate shoes are recommended!

10:30 – 12:30 *Bus trip from HCLA to Cajón del Maipo*
12:30 – 13:30 *Snack Lunch*
13:30 – 17:00 Free time: Trekking, Horse Riding, Rafting…
17:00 – 20:00 Wine tasting and dinner at La Tribu, Cascada de las Ánimas
20:00 – 21:30 *Bus trip from Cajón del Maipo to HCLA*

ESO's Very Large Telescope (VLT) at Paranal, the world's most advanced ground-based facility for astronomy.

MONDAY, NOVEMBER 24, 2014

FUNDAMENTALS; INTERFEROMETRY I

09:30 – 18:00 LECTURES

09:30 – 11:30 **Gerard van Belle,** Lowell Observatory: »History of optical interferometry«
Konrad Tristram, European Southern Observatory (ESO):
»The VLTI and its instrumentation – past, present, and future«
11:30 – 11:45 *Coffee break*
11:45 – 13:00 **Tom Herbst,** Max-Planck Institut für Astronomie: »The LBT Linc-Nirvana Instrument: Fizeau interferometry«
13:00 – 14:30 *Lunch*
14:30 – 16:30 **Andreas Glindemann,** European Southern Observatory (ESO): »Light propagation through the atmosphere«
Andreas Quirrenbach, Universität Heidelberg: »Theory of optical interferometry & observational basics«
16:30 – 16:45 *Coffee break*
16:45 – 18:00 **Gerard van Belle,** Lowell Observatory:
»US facilities including CHARA and NPOI« / »The Planet Formation Imager«
18:00 – 19:00 *Dinner*

TUESDAY, NOVEMBER 25, 2014

INTERFEROMETRY II; ADVANCED MODES: FRINGE TRACKING

09:30 – 16:30 LECTURES

09:30 – 11:30 **Andreas Glindemann,** European Southern Observatory (ESO):
»Principles of interferometry: interferometric field of view«
Andreas Quirrenbach, Universität Heidelberg: »Interferometer infrastructures: telescope delay lines«
11:30 – 11:45 *Coffee break*
11:45 – 13:00 **Gerard van Belle,** Lowell Observatory: »Intensity Interferometry«
13:00 – 14:30 *Lunch*
14:30 – 16:30 **Antoine Merand,** European Southern Observatory (ESO):
»Advanced interferometry modes I: fringe tracking; present instruments: FINITO, PRIMA«
Oliver Pfuhl, Max-Planck Institut für extraterrestrische Physik:
»Fringe-tracking: Future concepts and the implementation in GRAVITY«
16:30 – 16:45 *Coffee break*
16:45 – 18:00 CAREER SEMINAR
Thomas Henning, Max-Planck-Institut für Astronomie / **Leopoldo Infante,** Pontificia Universidad Católica de Chile: »International collaborations; FRINGE & career opportunities in Europe; Career opportunities in Chile & Latin America«
18:00 – 19:00 *Dinner*

WEDNESDAY, NOVEMBER 26, 2014

INTERFEROMETRY III

09:30 – 17:00 **LECTURES**

09:30 – 11:30 **Andreas Glindemann,** European Southern Observatory (ESO): »Multi-aperture combination, direct imaging«
Andreas Quirrenbach, Universität Heidelberg: »Reduction of interferometric data«

11:30 – 11:45 *Coffee break*

11:45 – 13:00 **Antoine Merand,** European Southern Observatory (ESO):
»Data modelling and the interpretation of interferometric data«

13:00 – 14:30 *Lunch*

14:30 – 15:45 **Antoine Merand,** European Southern Observatory (ESO): »Advanced modes II: spectro-interferometry«

15:45 – 16:00 *Coffee break*

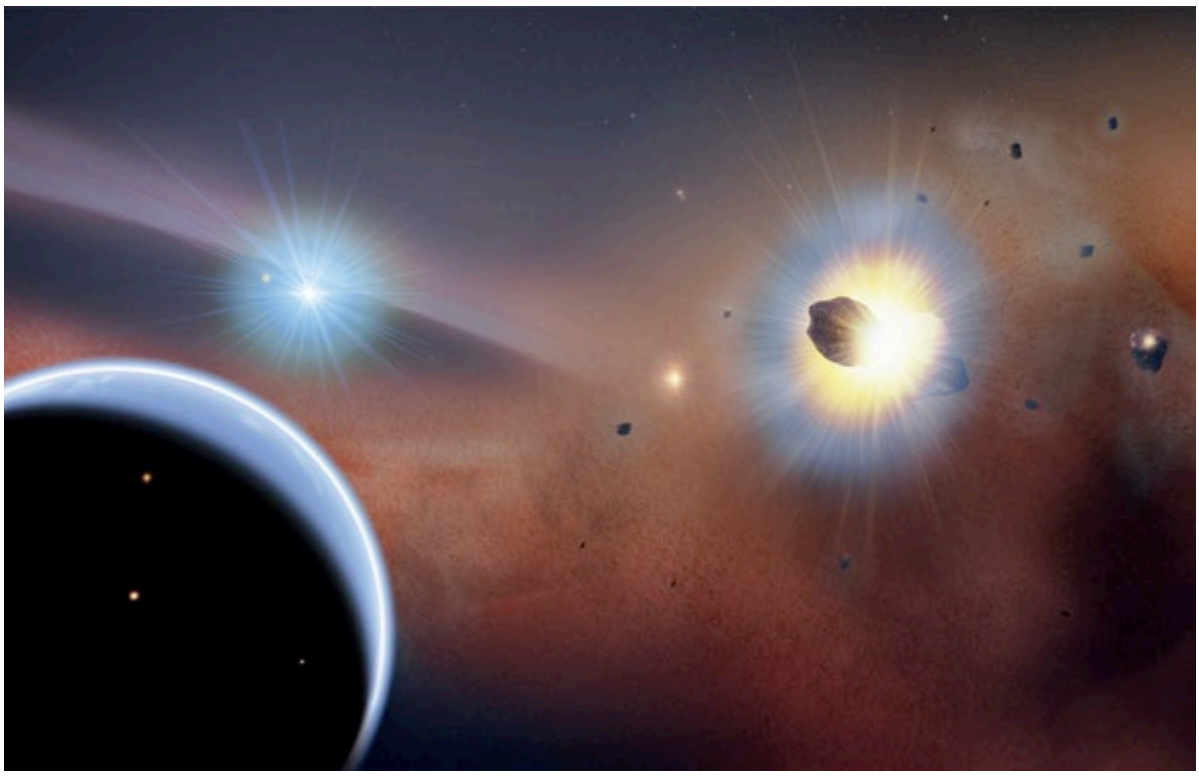
16:00 – 17:00 **Oliver Pfuhl,** Max-Planck Institut für extraterrestrische Physik:
»Advanced modes III: Micro-arcsecond astrometry with GRAVITY«

17:00 – 18:00 *Dinner*

18:00 *Transfer from HCLA to Planetarium*

19:00 – 20:30 **PUBLIC LECTURE,** Planetarium
Thomas Henning, Max-Planck-Institut für Astronomie:
»From Cold Molecular Clouds to the Birth of Exoplanets: The Discovery Machines«

20:30 *Transfer from Planetarium to HCLA*



INTERNATIONAL SYMPOSIUM
LIVE AS A PLANETARY PHENOMENON

THURSDAY, NOVEMBER 27, 2014

AUDITORIUM OF THE ESO VITACURA OFFICE

08:00	*Transfer from HCLA to ESO Vitacura Office*
09:00 – 09:30	**Introductory words**
09:30 – 11:00	**Thomas Henning** – Max-Planck-Institut für Astronomie: »Star formation including disks«
11:00 – 11:30	*Coffee break*
11:30 – 13:00	**Cornelis Dullemond** – Universität Heidelberg: »Complex structures in protoplanetary disks«
13:00 – 14:00	*Lunch*
14:00 – 15:30	**David Catling** – University of Washington: »Planetary atmospheres«
15:30 – 16:00	*Coffee break*
16:00 – 17:30	**Malcolm Fridlund** – Leiden University: »Astrobiology«
17:30 – 18:00	*Transfer from ESO Vitacura Office to HCLA*
18:30 – 19:30	*Dinner*

FRIDAY, NOVEMBER 28, 2014

AUDITORIUM OF THE ESO VITACURA OFFICE

08:00	*Transfer from HCLA to ESO Vitacura Office*
09:00 – 10:30	**Malcolm Fridlund** – Leiden University: »How to look for life«
10:30 – 11:00	*Coffee break*
11:00 – 12:30	**Andrés Jordán** – Pontificia Universidad Católica de Chile: »Search for exoplanets; HAT-S«
12:30 – 13:30	*Lunch*
13:30 – 15:00	**Manuel Guedel** – Universität Wien: »Planetary habitability – part I: Evolution of planetary host stars and their environments«
15:00 – 15:30	*Coffee break*
15:30 – 17:00	**Manuel Guedel** – Universität Wien: »Planetary habitability – part II: Astrophysical conditions for life«
17:00 – 17:30	*Transfer from ESO Vitacura Office to HCLA*
19:00	**Farewell Dinner,** HCLA

SATURDAY, NOVEMBER 29, 2014

Departure participants

This long-exposure shot taken at the VLT shows how the laser guide star moves across the sky through the night.

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ABSTRACTS OF SUMMER SCHOOL SPEAKERS

RODOLFO ANGELONI, GEMINI OBSERVATORY
The Bombolo Instrument
BOMBOLO is a new multi-band visitor instrument for the SOAR 4m Telescope. It is a three-arm imager covering the near-UV and optical wavelengths through an optimized set of broad and narrow band filters.
The three arms work simultaneously and independently, providing synchronized imaging capability for a variety of astronomical events. Its driving science cases are: 1) Flickering Studies of Accretion Phenomena; 2) Near UV/Optical Diagnostics of Stellar Evolutionary Phases; 3) Exoplanetary Transits; 4) Microlensing Follow-Up and 5) Minor bodies in the Solar Systems.
BOMBOLO is an exemplary case of science exploration feeding technology development in Chile. The instrument is at the Conceptual Design stage, having been approved by the SOAR Board of Directors as a visitor instrument in 2012 and having been granted full funding from CONICYT, the Chilean State Agency of Research, in 2013. The Design Phase has begun and will be completed in late 2014, followed by a construction phase in 2015 and 2016A, with expected Commissioning in 2016B and 2017A.

CLÉMENTINE BÉCHET, PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE
Requirements for tomographic adaptive optics systems
The classical adaptive optics systems can be used only over a few percent of the observable sky, defining the »sky coverage« of the instrument. This limited use is due to two fundamental issues: the turbulence anisoplanatism and the limiting magnitude of the reference stars. In this lecture, we present how tomographic adaptive optics systems can be designed to overcome these obstacles on the large and extremely large telescopes. The main parameters for the design of such systems are described together with their influence on the adaptive optics correction quality.
Although tomographic adaptive optics have now been demonstrated to work on 8 to 10-meter telescopes, the lecture will highlight the remaining challenges to make them possible on the coming generation of extremely large telescopes.

GAËL CHAUVIN, LABORATOIRE D'ASTROPHYSIQUE DE L'OBSERVATOIRE DE GRENOBLE
Fundamentals of adaptive optics: description of wavefronts
In this lecture, I will briefly review the basic concept and motivation of adaptive optics. I will start from the first principles of image formation with an optical instrument through the atmospheric turbulence. I will then continue with the main principles of wave-front sensing and reconstruction, deformable mirrors, control and error budget to conclude with the main current application of adaptive optics in astronomy.

GAËL CHAUVIN, LABORATOIRE D'ASTROPHYSIQUE DE L'OBSERVATOIRE DE GRENOBLE

Coronography and angular differential imaging; Imaging of extrasolar planets

With the development of high contrast imaging instruments and techniques, vast efforts have been devoted during the past decade to detect and characterize lighter, cooler and closer companions to nearby stars, and ultimately image new planetary systems. Complementary to other observing techniques, this approach has opened a new astrophysical window to study the physical properties and the formation and evolution mechanisms of giant planets at orbits larger than a few AUs. I will review the main motivations to use deep imaging to search for exoplanets and report the constant progress achieved thanks to improved performances of advanced instrumentation and data analysis techniques. I will then describe the various technological and processing steps that lead to a planet detection and characterization. I will then conclude briefly with the exciting perspectives offered with the new SPHERE and GPI planet imagers offered to the community in 2014.

JULIEN GIRARD, EUROPEAN SOUTHERN OBSERVATORY (ESO)

The AO – Zoo – GLAO, MCAO, XAO, LTAO ...

In this lecture, I will attempt to review exhaustively all types of adaptive optics (AO) systems implemented for astronomical purposes.

AO has split in many different flavours in the past decade and each of these flavours – with its physical and technological limitations – correspond to a set of applications and science cases (e. g. »Ground Layer« AO for wide-field applications, »Extreme« AO for high-contrast imaging of extra-solar planets and faint discs, etc.). I will discuss them, explore which type of AO can enhance which type of observations, how these ground based technologies can challenge and/or complement space born instrumentation, speak about the implementation (e.g with/without lasers), status and present some results coming from new AO systems.

JULIEN GIRARD, EUROPEAN SOUTHERN OBSERVATORY (ESO)

The VLT adaptive optics system; The VLT laser guide star

This lecture will focus on the adaptive optics (AO) systems »suite« available now or in the near future at the Paranal Observatory. Following my presentation about the »AO Zoo« and other AO related lectures, I will present how this suite is serving the needs of the community using nearly all flavours of AO. Some AO systems are integrated into single instruments (i.e NAOS for NACO, MACAO for SINFONI or CRIRES) and some AO systems are facility systems which can feed various instruments (i.e the AOF, the LGSF, the MACAOs for the VLTI, and to some extend, SAXO for the various SPHERE instrument). I will develop about how all these systems are integrated into our Science Operations model, how do we maintain and improve them, assess their performances with a set of metrics and quality control tools, how do we operate these complex systems (training of our staff, etc.) and meet the requirements of various challenging science cases.

ANDREAS GLINDEMANN, EUROPEAN SOUTHERN OBSERVATORY

Light propagation through the atmosphere

The imaging process in astronomy suffers from atmospheric turbulence perturbing the incoming light wave by random index of refraction fluctuations. This effect is caused by turbulent mixing of air with different temperature so that the image quality in large telescopes is far from the diffraction limit but corresponds to telescopes with a few 10cm diameter. Operating interferometers on the ground, the fringe pattern is wiped out unless the integration times are limited to a about 100 msec.

We will discuss the statistics of atmospheric turbulence as derived by A. N. Kolmogorov. Basic temporal and spatial parameters, like the Fried parameter, are given, and we will derive statistical quantities (OPD fluctuations, differential fringe motion, tip/tilt and wave front perturbations using Zernike polynomials) as a function of turbulence and instrumental parameters. The derived quantities will be used to investigate the limitations of observing through turbulence.

Finally, the twinkling of the stars, the scintillation will be investigated with the same methods, and speckle interferometry, as one of the early attempts to beat atmospheric turbulence, will be discussed.

ANDREAS GLINDEMANN, EUROPEAN SOUTHERN OBSERVATORY

Principles of interferometry: interferometric field of view

The beam combination scheme and the layout of the interferometer array determine the characteristics of the interferometer and its field of view. If the reimaged telescope apertures in the beam combining instrument are a downscaled replica of the interferometer array, the interferometric field of view is as large as that of the individual telescopes, limited by the optical design only. This is called the Fizeau configuration, after Hippolyte Fizeau who was one of the first to publish the idea of stellar interferometry in 1868.

While the Fizeau configuration permits to discuss the imaging process in close analogy to single aperture systems, there is another configuration playing a major role in interferometry, which is called Michelson configuration after Albert A. Michelson who together with Francis G. Pease was the first to measure stellar diameters with an interferometer on Mount Wilson, California, in 1920. In contrast to the Fizeau configuration, the configuration and the distances of the apertures in the beam combining instrument are chosen independently of the baselines in the interferometer array. The consequence is that the interferometric field of view in Michelson configuration is limited in size to less than the Airy disk of the individual apertures.

The pros and cons of both combination schemes will be discussed under practical and theoretical aspects.

ANDREAS GLINDEMANN, EUROPEAN SOUTHERN OBSERVATORY

Multi-aperture combination, direct imaging

In the last lecture (interferometric field of view), the discussion was centred on fringe patterns, their visibilities and on forming images through aperture synthesis, having a rather modest number of telescopes – typically fewer than 10 – in mind. In this lecture, the simultaneous combiniation of a very large number of telescopes will be discussed. We could then produce a PSF with a narrow central core and only few bumps and sidelobes, similar to an Airy disk, so that we instantaneously have a usable image.
This is a straightforward process in Fizeau configuration, forming an image with a field of view that is limited by the optical design of the telescopes only. Combining many telescopes in Michelson configuration there are several options. One concept called the Hypertelescope was proposed by A. Labeyrie in 1996. It relies on maximising the re-imaged telescope apertures in the exit pupil so that the gaps are minimised, a densified pupil is formed providing a PSF with a bright central core and without fringes. While it has advantages over the Fizeau configuration, its field of view is severely limited, deteriorating very quickly when going off-axis. Another concept was proposed by F. Vakili in 2004, who described the combination of the telescope apertures forming an image in the aperture plan, apparently contradicting all principles of classical image formation. The field of view is similar to that of the Hypertelescope, but its PSF is of constant quality over the field of view.

Literature for all lectures: A. Glindemann, Principles of Stellar Interferometry, Astronomy & Astrophysics Library, Springer-Verlag 2011

ROLAND GREDEL, MAX-PLANCK INSTITUT FÜR ASTRONOMIE

The E-ELT and its instrumentation

The European Extremely Large Telescope (E-ELT) is a revolutionary new ground-based telescope concept from ESO based on a five-mirror scheme.
The core concept includes a segmented primary mirror of 39m diameter, and a quaternary adaptive mirror supported by up to 8000 actuators. The two first light instruments include the diffraction limited near-infrared imager and a single-field near0infrared wide-band integral field spectrograph, including two adaptive optics systems.
The next three instruments will be a mid-infrared imager and spectrometer, a high-resolution spectrometer and a multi-object spectrometer.

ROLAND GREDEL, MAX-PLANCK INSTITUT FÜR ASTRONOMIE

Adaptive Optics with Luci 1&2 at the LBT

The two near-infrared instruments Luci 1 & 2 at the Large Binocular Telescope (LBT) will make use of the single conjugate adaptive optics system installed at the LBT. The innovative features of the LBT AO system are two adaptive secondary mirrors and the pyramid wavefront sensor located in The acquisition, guiding and wavefront sensing unit (AGW) mounted inside the instrument derotator. Luci 1 & 2 will provide diffraction limited imaging and long-slit spectrocopy with Strehl number exceeding 80% in the near-infrared wavelength regions.
The natural guide star operation of Luci 1 & 2 is complemented by ARGOS, the laser guide star facility for the LBT. ARGOS generates six laser guide stars which will be used to correct the ground layer turbulence, thus enhancing the imaging and spectroscopic capabilities of Luci over a 4'x4' field of view.

ANDRÉS GUESALAGA, PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE

Wide field adaptive optics

A new generation of adaptive optics (AO) systems called wide field AO (WFAO) mark the beginning of a new era in astronomical observations. By using multiple artificially generated laser guide stars (LGS), WFAO significantly increases the field of view of the AO-corrected images, and the fraction of the sky that can benefit from such correction. Standard AO systems are well suited for observations of bright and relatively compact objects, whereas this new generation of WFAO is opening the path for a multitude of new science studies.
Within a decade, the world will see a new generation of telescopes with diameter up to 39m, called the Extremely Large Telescopes (ELTs). These giants will address fundamental astrophysical science cases as for instance the direct imaging and characterization of exo-worlds or the study of bulk and evolution of the first galaxies. The scientific potential of these giants relies on challenging new AO concepts, integrated inside the telescope itself, and providing high-resolution images to all the instrumentation downstream.
In order to get the best science results out of the WFAO images, and to fully optimize the return of such complex systems, new tools are to be developed.
The talk starts with a brief introduction to these WFAO techniques and then some data reduction techniques are presented that seek to optimize the performance of such systems. Special emphasis is given to turbulence profilers, a key tool for optimal conjugation of DMs and for the assessment of the AO system. Applications of this tool to multi-conjugate AO (MCAO) and ground layer AO (GLAO) are discussed.

LEOPOLDO INFANTE, PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE

Observing the past: from photons to data product to science (Public Lecture)

Shortly after the Big Bang, about 100 to 200 thousand years, the radiation manages to travel almost freely through the universe. Time after, 13.7 billion years, our age, we observe this radiation with telescopes on Earth. Along the way, the radiation passes through large structures of matter. Information about these structures gets impregnated in it. There are thousands of millions of years of evolution that we can scrutinize and decipher today with our telescopes.
In this talk I will use examples, based on our experience, to tell the story of our physical world.

ANDREAS KAUFER, EUROPEAN SOUTHERN OBSERVATORY (ESO)

ESO and its instrumentation programme

The European Southern Observatory (ESO) currently deploys the second generation of instrumentation at its four 8.2-m Unit Telescopes of the Very Large Telescope (VLT) at Paranal. The second generation of interferometric instruments is currently being built in Europe and is expected at the Observatory in the next two years. This new generation of state-of-the art instruments brings outstanding new observing capabilities and science opportunities to the astronomical community after 15 years of successful VLT science operation.
In this lecture we will obtain an overview of the capabilities of the VLT's current and future instrument suite and learn about the strategies ESO applied to define, construct, deploy and operate it. We will share some of the technical and managerial challenges encountered during the course of this ambitious instrumentation programme and discuss the lessons learned.
During our visit to the Paranal Observatory on Friday, November 21, we will have the opportunity to have a closer look at some of the 17 operational instruments and their day and night time operation.

DIMITRI MAWET, EUROPEAN SOUTHERN OBSERVATORY (ESO)
Wavefront correction: deformable mirrors
In this lecture, I will review the main drivers for the design of deformable mirrors. I will present all four families of deformable mirror technologies that have successfully been used in astronomical applications over the past 25 years: electrostrictive, MEMS, voice coil, bimorph. I will then discuss their respective advantages and drawbacks in the context of different adaptive optics usage (classical AO, wide-field AO, extreme AO on the ground and in space). Finally, after presenting the main manufacturers in this domain, I will discuss the requirements, challenges and perspective for the future of deformable mirror technologies.

DIMITRI MAWET, EUROPEAN SOUTHERN OBSERVATORY (ESO)
The VLT Exoplanet imager Sphere
SPHERE is the latest second generation instrument to arrive at the VLT, and it is currently nearing the completion of its commissioning phase. SPHERE is a high contrast imaging facility, equipped with an extreme adaptive optics system, a suite of new generation coronagraphs, and three science sub-systems: the near-infrared dual-beam imager IRDIS, the integral field spectrograph IFS, and ZIMPOL, the visible simultaneous differential polarimeter. In this lecture, I will show in details why and how SPHERE is fine tuned to perform high contrast imaging of young planetary systems to detect and characterize gas giant planets caught in their early formation stage. Thanks to its outstanding image quality and dynamic range, SPHERE will also image and characterize circumstellar disks. This unique instrument will be a powerful tool for other science fields that I will also briefly review in this talk.

ANTOINE MERAND, EUROPEAN SOUTHERN OBSERVATORY (ESO)
Advanced interferometry modes I: fringe tracking; present instruments: FINITO, PRIMA
Fringe tracking is the active technique used to stabilized the optical path delay in order to phase continuously an interferometer. We present briefly the basic principle of this technique as well as some application at VLTI, using the FINITO and PRIMA fringe trackers, in particular post processing of data.

ANTOINE MERAND, EUROPEAN SOUTHERN OBSERVATORY (ESO)
Data modelling and the interpretation of interferometric data
Optical Interferometry does not provide direct astrophysical informations and require to model interferometric quantities from models. We will introduce basic principles to measure quantities using interferometry. We will also introduce basic principles of error propagations and bias estimation.

ANTOINE MERAND, EUROPEAN SOUTHERN OBSERVATORY (ESO)
Advanced modes II: spectro-interferometry
Spectro interferometry combines spectroscopy to interferometry. We will present basic principles of the technique and the unique applications it offers, in spite of its intrinsic limitations. This mode relies on fringe tracking, which was introduced previously.

OLIVER PFUHL, MAX-PLANCK INSTITUT FÜR EXTRATERRESTRISCHE PHYSIK (MPE)
Fringe tracking: Future concepts and the implementation in GRAVITY
Fringe tracking is a key technology for interferometry to overcome the limitations imposed by the turbulent atmosphere. Efficient controllers and algorithms have to be robust against instrumental vibrations, flux drop-outs and changing atmospheric conditions.
In this lecture, I will discuss different algorithms to estimate the atmospheric OPD for a 4-telescope array such as the modal- and the piston approach. The most widely used fringe tracking control-scheme is the classical integrator control, which is robust and easy to implement however performs poorly when confronted with vibrations. In the presence of vibrations and at low SNR levels more advanced control-schemes such as the Kalman control outperform classical controllers. I will compare the different control schemes and discuss their limitations.
Finally I will present the fringe tracker of the second-generation VLTI instrument GRAVITY.

OLIVER PFUHL, MAX-PLANCK INSTITUT FÜR EXTRATERRESTRISCHE PHYSIK (MPE)
Advanced modes III: Micro-arcsecond astrometry with GRAVITY
The instrument GRAVITY is designed to deliver 10 micro-arcsecond astrometry on faint objects. The prime science goals of the instrument are to study accretion events of the Galactic Center supermassive black hole in real time and to observe general relativistic effects on the motion of the stars surrounding the black hole.
In this lecture I will introduce the concept of micro-arcsecond astrometry with interferometers and present the technical realization in GRAVITY. From theory to practice; I will discuss some of the nasty details that make astrometry so hard in real life.
Finally I will conclude with the science perspectives and limitations of GRAVITY.

KONRAD TRISTRAM, EUROPEAN SOUTHERN OBSERVATORY (ESO)
The VLTI and its instrumentation – past, present, and future
The Very Large Telescope Interferometer (VLTI) coherently combines the light of the four fixed Unit Telescopes or the four relocatable Auxiliary Telescopes of the VLT. In this lecture I will give an overview over the infrastructure of the VLTI, including its current and future instrumentation. After a short historical introduction, I will trace the path of the light coming from the telescopes, passing the delay lines and reaching the interferometric laboratory where the light is combined in the interferometric instruments. I will then focus on the past and current instrumentation suite of the VLTI, presenting the technical concepts and operation modes of the individual instruments. For every instrument I will also describe their scientific goals and highlight a few scientific results ranging from the charting of stellar surfaces or the dust disks surrounding young stars to the dusty environments of active galactic nuclei. Finally I will present the plans for the future of the VLTI, most notably the upcoming second generation VLTI instruments that are due to be installed at the VLTI in the next years.

GERARD VAN BELLE, LOWELL OBSERVATORY
History of optical interferometry
A review of the history of optical interferometry will be given, starting with the early seeds of the technique in the late 19th century. The overall development of the technique & technology, in comparison to the advances of astrophysics itself, will be examined through the 20th century. This rich tapestry of successes and failures sets the stage for the current generation of efforts on the bleeding edge of astrophysical instrumentation.

GERARD VAN BELLE, LOWELL OBSERVATORY

US facilities including CHARA and NPOI

The current status of operational faciltiies in the United States will be examined, including Georgia State University's (GSU) Center for High Angular Resolution Astronomy (CHARA) Array, and the Navy Precision Optical Interferometer (NPOI). This will include a discussion of each facility's infrastructure, and the range of available back-end instrumentation. Prospects for each facility's future, including facility enhancements, will be considered. Some commentary on the under-development Magdalena Ridge Observatory Interferometer (MROI) will also be presented as part of the US landscape.

GERARD VAN BELLE, LOWELL OBSERVATORY

The Planet Formation Imager

The Planet Formation Imager (PFI) is a new, international effort to build upon the successes of optical interferometry in the design of a new facility, uniquely suited to address the fascinating and hotly-debated challenge of understanding planetary formation. The PFI project has crystallized around this challenging goal: to deliver resolved images of Hill-Sphere-sized structures within candidate planet-hosting disks in the nearest star-forming regions. Solving the riddle of planetary formation has profound and far-reaching implications beyond astronomy, for it helps inform our place in the universe and expectations for life on other worlds.

GERARD VAN BELLE, LOWELL OBSERVATORY

Intensity Interferometry

The most-cited interferometry papers of all time at visible wavelengths are the intensity interferometry (I^2) works by Robert Hanbury Brown (1956, 1974). However, I^2 is a largely forgotten and even derided technique in modern short-wavelength interferometry circles. How is this possible? An consideration of the technique and its history will open the discussion. A review of the motivations and prospects for a modern revival of I^2 will then be examined.

ABSTRACTS OF SYMPOSIUM SPEAKERS

CORNELIS DULLEMOND, UNIVERSITÄT HEIDELBERG
Complex structures in protoplanetary disks
With recent advances in adaptive optics it has become possible to see complex and interesting non-axisymmetric structures in the scattered light images of protoplanetary disks. These structures often have spiral features. At the same time, using millimeter interferometry with ALMA very non-axisymmetric structures are found in thermal emission from dust grains: lopsided continuum blobs are often seen in addition to ringlike structures. How do we interpret these, and why do the structures seen in millimeter waves look different from those seen in scattered near-infrared light? I will talk about how we try to answer these questions by making hydrodynamic models of protoplanetary disks and postprocessing these using 3-D radiative transfer calculations.

MALCOLM FRIDLUND, LEIDEN UNIVERSITY
ASTROBIOLOGY
While we know there is life in the Universe (i.e. here), we do not know how common it is (»Are we alone?«), how it arose, how it evolves and how it may end (sometimes prematurely). In this lecture, we make an introduction to the topic covering the following items: The possibility of life beyond the Earth, The scientific and philosophical rationale for a search, and how life arose and evolved on the Earth, and how common it is.
Astrobiology is a relatively new science that suffers from a lack of data. It therefore have to make do with, to a large extent, to try to model the origin and evolution of life on the Earth and then extrapolate those models to the emerging knowledge about the conditions on exoplanets. This worked fine before the discovery of the first exoplanet (in 1995), when it was solidly expected that all (or essentially all) exo-systems would look exactly like our own Solar System. With the growing realization that this is not so – since no exact analogue of our own system have been discovered to date – Astrobiology have to adapt to try to estimate the possibility of life outside our Solar System under conditions that are very different.

MALCOLM FRIDLUND, LEIDEN UNIVERSITY
HOW TO LOOK FOR LIFE
In this lecture we adress the issues of »Where to search for extra-terrestrial life« and »How to carry out such a search«.
We thus touch on the issue on how we will go about to settle the question of if there is life out there somewhere and what kind of instruments we may use to go about it. In this talk we focus on space based applications. Both the strategy and the actual technology that can be used will be detailed based on detailed studies carried out by the major space agencies NASA and ESA.

MANUEL GUEDEL, UNIVERSITÄT WIEN

Planetary habitability I: Evolution of planetary host stars and their environments

The evolution of planetary habitability critically depends on the evolution of the host stars and their environments. After their formation, stars maintain a very complex environment controlled by the stars themselves, by external factors such as circumstellar disk dynamics, and by the interplay between stellar and disk processes.
Magnetic fields play a central role in most of these mechanisms, driving disk accretion, launching jets, accelerating stellar winds, heating stellar atmospheres and therefore giving rise to high-energy particles and radiation. The latter in turn ionizes and heats gas in the stellar environment, including protoplanetary disks but also atmospheres of young planets. As young stars lose their disks and approach the main sequence, their immediate environments go through their most violent, magnetically driven phases. This stage is concurrent with the critical stages of the final assembly of planets and the formation of their early atmospheres. Once on the main sequence, gradual stellar spin-down leads to a progressive decline of magnetic activity; while we know relatively well what this implies for energetic radiation, rather little is known about the development of particle fluxes and stellar winds, but some trends become apparent from theoretical and comparative studies. In this presentation, I discuss the current general knowledge of these processes from the stages of early star formation to the end of the main sequence for solar-like and lower-mass stars.

MANUEL GUEDEL, UNIVERSITÄT WIEN

Planetary habitability II: Astrophysical conditions for life

Habitability on planets is the result of a complex interplay between many factors, some of which are predominantly "geophysical" in nature, while others are driven by the astrophysical environment of the planets; some of the key processes leading to habitable planets are indeed related to the reaction of planetary magnetospheres, atmospheres and surfaces to the "astrophysical" environment of the planets. This presentation summarizes a number of astrophysical mechanisms that are crucial conditions for habitability. I will address some important dynamical processes in early planetary systems such as scattering and collisions of bodies, processes that are also important for water transport; I will next address the formation and evolution of the earliest planetary atmospheres in the context of protoplanetary disks and discuss the possible evolutionary paths of such protoatmospheres under the influence of the energetic environment of young host stars.
Magnetized winds and energetic particles are also important for the further processing of planetary atmospheres and their long-term protection. Examples in the solar system will shed some light on what can "go wrong" in the development of habitable environments on planets, suggesting what places to look for in our search for planets conducive to life.

ANDRÉS JORDÁN, PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE

Search for exoplanets; HAT-S

Over a thousand exoplanets have been discovered since the first landmark discoveries about 20 years ago. I will briefly review the main features we have learned about exoplanetary systems from the systems uncovered to date, focusing on transiting exoplanets, the systems that allow for a better characterization of their physical properties. Transiting exoplanets have been uncovered by space and ground based experiments, and as an example of the latter I will describe HATSouth, a global network of fully automated wide-field telescopes with stations in Chile, Namibia and Australia. I will describe in detail the design, operations and first results of this project.

DESCRIPTION OF DOCTORAL PROJECTS

DANIEL AGUIRRE AGUIRRE, INSTITUTO NACIONAL DE ASTROFÍSICA, ÓPTICA Y ELECTRÓNICA (INAOE)
Dynamic Null Ronchi test
The main objective of the thesis is the validation for ReRRCA algorithm. This was proposed to obtain the wavefront aberrations of synthetic and experimental Ronchigrams, using only one Ronchigram without the need for polynomial fits or trapezoidal integrations. In order to validate the proposed analysis, the polynomial aberration coefficients which were used to generate the simulated Ronchigrams were retrieved. The results were published in International Journals.

NARSIREDDY ANUGU, UNIVERSIDADE DO PORTO
Astrophysics, instrumentation
GRAVITY is a 2nd generation ESO-VLTI instrument for high precision astrometry and imaging. The work is on the integration, testing and software development for the Acquisition Camera. This subsystem aims at simultaneous pupil tracking/imaging, object tracking and wavefront aberration sensing of the four telescopes optical beams. This part is now ending and the student will then proceed to the astrophysical exploitation, on binary stars orbital fitting.

SANTIAGO BARBOZA, UNIVERSITÄT STUTTGART
»Mechanical Design of a Large Image Derotator for an Infrared Camera« within the international MICADO consortium
MICADO is the Multi-AO Imaging Camera for Deep Observations (MICADO), which is being designed to work with adaptive optics at the E-ELT. My PhD thesis will focus on developing MICADO's derotator, a key mechanical component that must carry the cryostat (1.5 tons) and the wave-front sensor while connecting them to the support structure and at the same time, must stably derotate the whole instrument around its vertical axis of symmetry.

RAFAEL BRAHM, PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE
Detection and characterization of extrasolar planets
My research focuses on the detection and characterization of transiting extrasolar planets (TEPs) via the HATSouth project. TEPs are fundamental for validating theories of formation, structure and evolution of exoplanets, because only for those systems we can estimate their mass and radius, which give us an idea of their bulk density. I want to increase the sample of well characterized TEPs by enlarging the parameter space. HATSouth is a global Network with 3 stations located at three sites of the southern hemisphere which allows the continous monitoring of our fields avoiding the diurnal cycle. These feature increases the probability of detecting planets with periods greater than 5 days. I am also interested in detecting transiting hot Neptunes which have been poorly studied due to the small available sample. These objects lie in the transition of super Earths and hot Jupiters and a detailed study can help us in understanding the formation processes of exoplanetary systmes.

FAUSTINE CANTALLOUBE, UNIVERSITÉ DE GRENOBLE
Image processing methods based on inverse problem solving to detect and characterize exoplanets from ground-based telescopes data
The purpose of the PhD is to develop methods to extract information about stellar nearby environments such as the presence of companions, by solving inverse problems using a Bayesian approach. This kind of method requires an accurate imaging model as well as prior knowledge both on the instrument and on the sought objects. This work is primarily motivated by the development of new generation instruments like SPHERE at ESO and GPI at Gemini, with the longer term perspective of future E-ELT instruments.

BRUNELLA CARLOMAGNO, UNIVERSITÉ DE LIÈGE
Development of next generation vector vortex coronagraphs
The direct detection of exoplanets requires the use of dedicated, high contrast imaging instruments. In this context, vector vortex coronagraphs (VVC) are considered as one of the most promising solutions to reach high contrast at small angular separations. My research project aims to improve the design and performance of VVC based on subwavelength gratings, to contribute to their manufacturing and laboratory validation, and to carry out performance simulations for future E-ELT instruments.

ÁNGELA CORTÉS, PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE
Cn2 Profiler for a Multi-Conjugated Adaptive Optic System
My research topic focused on a SLODAR based technique, with the aim of measuring the strength of the layers of the atmospheric turbulence above the telescope using a Multi-Conjugate Adaptive Optics system. The theoretical basis was validated by on-sky data from the GeMS instrument with 5 laser guide stars. With correlation techniques, I was able to obtain a turbulence profile that can be used for real time optimization of the system performances.

PASCALINE DARRÉ, UNIVERSITÉ DE LIMOGES
ALOHA (Astronomical Light Optical Hybrid Analysis) / CHARA project at 1,55 µm
My research contributes to the development of a stellar interferometer using properties of nonlinear optics: the ALOHA (Astronomical Light Optical Hybrid Analysis) project. For almost ten years the team has validated the general principle in high flux level configuration and in photon counting regime. My researches focus on improving the signal-to-noise ratio of our instrument with the characterization of different nonlinear components, the identification of noise sources and the ability to operate with broadband spectrum. The laboratory demonstration will be tested on-sky with the CHARA telescope array.

NÉSTOR ESPINOZA, PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE
Unveiling exoplanet atmospheres with the ACCESS Survey
My research project focuses on the detection and study of exoplanetary atmospheres. In particular, my work for the ACCESS survey will allow me to study a significant number of exoplanet atmospheres, and to search for correlations between different atmospheric compositions and stellar and/or planetary parameters (e. g., can we predict hazes on a planetary atmosphere?).

DAVIDE GREGGIO, UNIVERSITÀ DI PADOVA
Dealing with wide fields of view: from ground to space
My PhD project will concentrate on the optical design, optimization and characterization of wide field (and high resolution) imagers both for space and ground based telescopes. In particular I will work on the optical design of the JANUS camera for the JUICE space mission by ESA and on the characterization of the performances of MICADO, the first light camera for E-ELT.

SEBASTIAAN HAFFERT, LEIDEN UNIVERSITY
Wavefront sensing for high contrast polarimetry imaging
Integration of a new wavefront sensor for high constrast polarimetry imaging. This wavefront sensor will be based on optical differentation using polarization, which should give an increase of information for polarimetry.

ROBERT HARRIS, DURHAM UNIVERSITY
Photonic Spectroscopy
My PhD project looks at the viability of using (photonic) technologies developed for the telecommunications industry within astronomy. It began by comparing equivalent photonic and conventional instruments to ascertain where the technology could be viably used. From this I then constrained the science cases, looked at designs and in the past year have built and demonstrated one of the devices on-sky.

FRANCISCO ANDRÉS IGLESIAS, MAX PLANCK INSTITUTE FOR SOLAR SYSTEM RESEARCH / TU BRAUNSCHWEIG
Fast Solar Polarimeter
The Fast Solar Polarimeter is a novel, ground-based, imaging polarimeter currently under development at MPS. The main goal of the instrument is obtaining full Stokes images with modulation frequency and duty cycle high enough to both considerably reduce the seeing-induced crosstalk and allow the implementation of post-facto, image reconstruction techniques. We mainly aim to detect fine, small-scales polarimetric signals like those present in quiet sun regions.

RAFAEL IZAZAGA PEREZ, INSTITUTO NACIONAL DE ASTROFÍSICA, ÓPTICA Y ELECTRÓNICA (INAOE)
Off-axis mirror fabrication from spherical surfaces under mechanical stress
The main objective of the thesis project is to implement an optical fabrication method for off-axis conical mirrors by using spherical surfaces under mechanical stress and the conventional polishing process. Interferometric optical tests are used to monitor the fabrication process and finite element analysis to verify the deformation accuracy, the importance of the project is the applicability of these components in astronomical instrumentation, in particularly for spectrograph.

ZAÍRA MODROÑO BERDIÑAS, INSTITUTO DE ASTROFÍSICA DE ANDALUCÍA
Discovering Earth like Planets around Cool Stars through the Radial Velocity technique
I am involved in CARMENES, a project to build and exploit a planet hunter working simultaneously in the visible and the near infrared, at IAA-CSIC. In particular, I am leading the development of RadiCa2D, a prototype designed to reduce the radial velocity errors derived from a non-homogeneous illumination of the fibres which feed non-thermally-stabilized, fibre-fed spectrographs. I am also studying aspects related with the physics of M stars (planets and pulsations).

ANDREA FERNANDA MUÑOZ, POTOSÍ INSTITUTO NACIONAL DE ASTROFÍSICA, ÓPTICA Y ELECTRÓNICA (INAOE)
Deflectometry with a Hartmann screen for measuring convergent optical systems
In my doctoral project we propose to use the deflectometry technique using a screen close to the system convergence point under test in order to test convergent optical systems. We are planning to implement it, for testing optical surfaces for use in telescopes, especially in the Guillermo Haro telescope of the National Observatory, located at Cananea, Sonora, Mexico. The main advance of this propose is the uses of coherent or incoherent light and its insensibility to mechanical noise.

After the Sun sets at ESO's Paranal Observatory darkness descends, but the black sky is speckled with a glorious myriad of sparkling stars.

SAAVIDRA PERERA, DURHAM UNIVERSITY
Optical Turbulence Profiling
The research project includes the development, deployment and exploitation of site-testing instruments at observatory sites to improve our understanding of seeing and its effects on astronomical telescope observations. The work aims to contribute to reducing effects of seeing and scintillation for exoplanet transit measurements, and for similar high time-resolution observations from the ground.

BENJAMIN POPE, UNIVERSITY OF OXFORD
Kernel Phase and Interferometry for Detection of Exoplanets and Disks
I am working on developing and applying new techniques in interferometry and extreme adaptive optics, for imaging stellar environments at the epoch of planet formation. My project will involve testing and deploying kernel phase interferometry on VLT with extreme AO for direct imaging of faint companions, and combining this with long-baseline interferometry to study transitional disks. I am interested in adaptive optics and interferometry instrumentation, Bayesian methods, and star and planet formation.

KALYAN RADHAKRISHNAN, UNIVERSITÄT HEIDELBERG
Integration, Testing and Scientific Exploitation of the LINC-NIRVANA instrument
My PhD thesis is based on the Optimization, Implementation and Scientific Exploitation of the LINC-NIRVANA instrument. Currently, the instrument is in the AIV phase at MPIA, Heidelberg and I am a part of this team. One of the preliminary tasks is to develop algorithms to realize layer-oriented multi-conjugated adaptive optics from the partially non-illuminated pupil images obtained from the mid-high wavefront sensor. I will also be a part of the different commissioning runs of the instrument.

BRENDA VILLALOBOS MENDOZA, INSTITUTO NACIONAL DE ASTROFÍSICA, ÓPTICA Y ELECTRÓNICA (INAOE)
Optical testing/ Interferometry
The main objective in my work is to develop a new method for testing optical surfaces that are manufactured in the Optics Workshop of INAOE. For this, we propose a new method to obtain the local deformations of an optical system, using a Spatial Light Modulator (SLM) placed in one arm of a Twyman-Green interferometer. The phase shifting is achieved by displaying the different gray levels on the SLM and with this we can obtain the local deformation of the wavefront , increase spacial resolution and know the shape of the surface under test.

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