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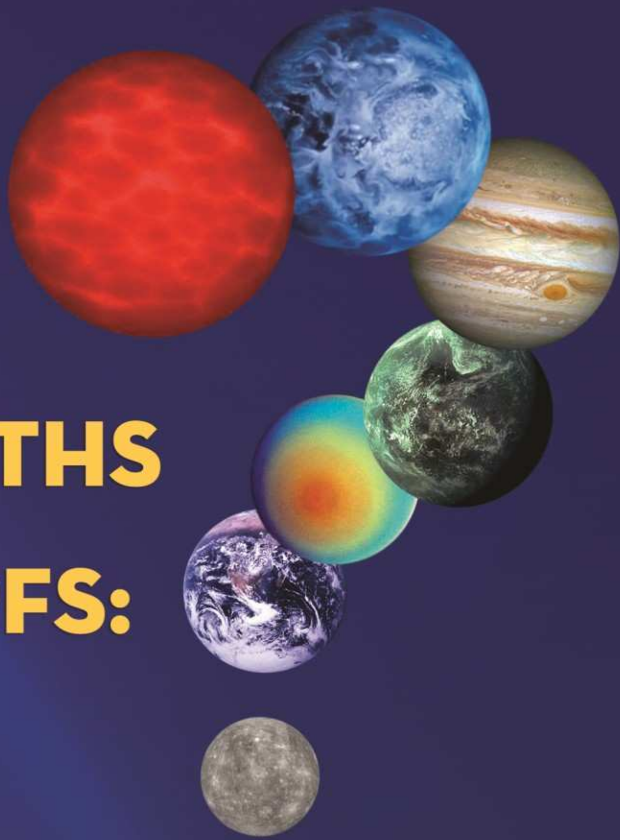
ABSTRACTS BOOK



FROM SUPER-EARTHS TO BROWN DWARFS: WHO'S WHO?

LIST OF PARTICIPANTS - INVITED AND CONTRIBUTED PAPERS - POSTERS

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ABSTRACTS

OF ORAL COMMUNICATIONS

Monday 29$^{\text{th}}$ June, morning chair: *Jack LISSAUER*

Who's Who: does living in Solar System mislead us?

Invited review

Jérémy LECONTE

Canadian Institute for Theoretical Astrophysics, Toronto - CANADA

After millennia of observations of our Solar System, planet formation and its possible outcomes seemed to be well understood... until exoplanets came around. On the one hand, we now know that most planets out there do not look anything like what we have around here. Yet, we keep trying to categorize new objects by using a classification born from the planets we know: super-"Earth" s, mini-"Neptune" s, hot-"Jupiter" s... On the other hand, while Solar System planets are, a posteriori, only a limited set of particular outcomes among the huge variety of possibilities offered by planet formation, they offer exquisite constraints that remain unrivaled by planets around other stars. Telluric planets, ice giants, gas giants... How did these categories come to be? What did these exquisite constraints allow us to learn about the structure and composition of their members? Does this knowledge help us understand the extreme diversity of extrasolar planets? Here are a few of the questions that this review will try to address.

Exoplanets sharing origin with Uranus

Radoslaw POLESKI

Department of Astronomy, The Ohio State University, Columbus - USA

The only known exoplanet that is an analog of the Solar System ice-giants is OGLE-2008-BLG-092LAb, which was discovered using microlensing technique. Its 18 AU separation from a 0.7 $M_{\odot}$ host makes it inaccessible for other detection methods. The large separation also suggests that origin of this exoplanet is similar to Uranus and Neptune i.e., it was formed closer to the host and migrated outward. The better understanding of ice-giant formation would require many more such exoplanets to be found using microlensing technique. I will present how the Uranus analog was discovered, discuss the prospects for finding a large sample of similar planets, and show connection between these and the free-floating planets.

Planetary structure revisited using ab initio equations of states

Stéphane MAZEVET

LUTH, Observatoire de Paris, Meudon - FRANCE

Using ab initio molecular dynamics simulations, we calculate equation of states for five main constituents of planetary interiors: H, He, H_2O, SiO_2 and Fe. These equations of states are multi-phases, include liquid solid phases and for silica and iron a melting curve calculated using the two-phases approach up to 1000 Mbar. Using a physically based parametrization of these results, we calculate planetary models for earth-type exoplanets, ice giants, and giants up to 10 times the mass of Jupiter. We also investigated the state of the core for Saturn and Jupiter and found that the hypothesis of a solid core is not compatible with these new EOS.

Co-authors: T. Tsuchiya, R. Musella, J. Bouchet, F. Guyot, A. Licari, F. Soubiran, G. Chabrier

Towards a new model of atmospheric tides: from Venus to super-Earths

Pierre AUCLAIR-DESROTOUR

IMCCE, Observatoire de Paris - FRANCE

Tides can strongly affect the evolution of the spin of planets. Super-Earths presenting a solid core and an atmosphere are submitted to both gravitational tides caused by bodies mutual gravitational interactions and thermal tides resulting from stellar insolation. Thermal tides are particularly important for planets in the habitable zone where they drive the tidal response of the atmosphere (Correia & Laskar 2008). They play a key role for the equilibrium states of the spin, as in the case of Venus (Correia & Laskar 2004) and of exoplanets (e.g. the numerical simulations by Leconte & al. 2015). Given the complex mechanisms involved in thermal tides, analytic models are essential to understand the dependence of the perturbation on the physics on the atmosphere and the tidal frequency. The one proposed in the 60s by Lindzen and Chapman explains well thermal tides in the asymptotic regime of fast rotators but presents a singularity near synchronization. We will present a new analytic approach that generalizes these early works to all regimes of tidal perturbations. This model describes the mechanisms of tidal waves generated in the atmosphere by both gravitational and thermal tides.

Planet heating as a safety net against inward migration of planetary cores

Frédéric MASSET

Instituto de Ciencas Fisicas, UNAM - MEXICO

One major outstanding problem in planetary migration theory concerns the fast inward migration predicted for embryos smaller than 35 Earth masses, as embryos of larger mass can be subjected to strong positive torque which prevent them to migrate quickly toward their star. With only inward migration, smaller mass embryos can only rarely engender giant planets located at Earths distances and beyond, in contrast with observational statistics. Here we introduce a new mechanism, the heating torque, that may constitute a solution to this problem. Instead of assuming the embryo to be a passive point-like mass, we incorporate the fact that infalling material raises the embryos temperature, thereby heating nearby disc regions. Asymmetries in the heated material produce a force that counteracts inward migration. This provides a channel for the formation of giant planets and also explains the strong planet-metallicity correlation found between the incidence of giant planets and the heavy elements abundance of the host stars.

Mapping Exoplanet Discoveries into Exoplanet Populations

Invited review

Natalie BATALHA

NASA Ames Research Center, Moffett Field - USA

This year, we mark twenty years of exploring the diversity of planets and planetary systems orbiting main sequence stars. Exoplanet discoveries spill into the thousands, and the sensitivty boundaries continue to expand. NASA's Kepler Mission unveiled a galaxy replete with small planets and revealed populations that don't exist in our own solar system. The mission has yielded discoveries and sensitivity measurements sufficient for computing planet occurrence rates as a function of size, orbital period, and host star properties. We have learned that every late-type star has at least one planet, that terrestrial-sized planets are more common than larger planets within 1 AU, and that the nearest, potentially habitable earth-sized planet is likely within 5 pc. I will review our current understanding of exoplanet populations and the challenges of transforming the observed population into an intrinsic population of planets in the galaxy.

Do Smaller Stars Really Host Smaller Planets?

Eric GAIDOS

Dept. of Geology & Geophysics, UH Manoa, Honolulu - USA

Analysis of sub-Neptune-size planets detected by Kepler have revealed a tentative but intriguing difference in the radius distribution of those planets hosted by M dwarfs compared to solar-type stars. While the distribution for the latter is nearly flat below about 2 - 3 Earth radii, the former seems to peak sharply at around 1 Earth radius. This difference may be an important clue to the properties and formation mechanism of these objects. However, the radius distribution of transiting planets depends on accurate determinations of stellar radius and density for stars with detected planets and for the overall target star catalog. M dwarfs have previously been less amenable to such estimates because of their complex spectra and non solar-like interiors. We applied relations between observables (magnitudes and colors) and stellar properties based on a recently published set of precise M dwarf calibrations to all cool (red) Kepler target stars. We performed a uniform, Gaussian process-based analysis to separate M dwarfs and giants, estimate effective temperatures, metallicities, radii, luminosities, and masses for the dwarfs. We revised the planet properties based on the revised stellar properties and new surveys for stellar companions that candilute the transit signal or change the transit duration. We then applied a novel method of iterative simulation to determine the planet radius distribution without resorting to binning and compared this to that derived from solar-type stars.

The Compositions of Small Planets

Invited review

David CHARBONNEAU

Harvard Center for Astrophysics, Cambridge - USA

The NASA Kepler Mission has demonstrated that planets with radii larger than Earth yet smaller than Neptune are common around Sun-like stars. Although Kepler has determined the physical sizes of hundreds of such planets, we know virtually nothing about their masses and, by inference, their compositions. HARPS-N is an ultra-stable fiber-fed high-resolution spectrograph optimized for the measurement of very precise radial velocities. Using HARPS-N we have measured to high precision the masses of several of these so-called super-Earths. I will report on the resulting constraints on the planetary compositions, and address the transition from terrestrial planets, made of rock and iron, to Neptune-like worlds, which have accreted and retained an envelope of primordial H/He gas. I will then explain the essential role of the NASA Transiting Exoplanet Survey Satellite (TESS), scheduled for launch in 2017.

Using Photo-Evaporation to Understand Super-Earths and Sub-Neptunes

Eric LOPEZ

Institute for Astronomy, U. of Edinburgh - UNITED KINGDOM

Recent surveys have uncovered a large new population of highly-irradiated super-Earth and sub-Neptune sized planets. Understanding these planets poses a fundamental test for models of planet formation and evolution. Are these mostly rocky planets that formed close to their current orbits, or are they ice-rich planets that migrated from beyond their snow-lines? I will discuss how discuss how these planets are sculpted by atmospheric photo-evaporation and how this process varies for different atmospheric compositions. I will then examine how we can use photo-evaporation to constrain the water-content and therefore the origin of the short-period sub-Neptunes and super-Earths.

Masses and Densities of Planets 1 - 4 times the Size of Earth

Geoffey MARCY

University of California, Berkeley - USA

We have measured the masses and densities of 30 transiting planets having a size, 1 - 4 Earth-radii. We show that those with radii near 1.5 Earth - radii usually have densities of 5 - 10 g/cm^3, consistent with a largely rocky composition. Larger planets, in the radius range 1.5 - 4.0 Earth-radii, have densities that decline with increasing radius, indicating increasing amounts of low-density material (H and He or ices) in an envelope surrounding a rocky core, consistent with the term "mini-Neptunes".

Theoretical Perspectives on Rocky Planets

Invited review

James KASTING

Penn State University, University Park - USA

Both rocky planets and gas/ice giant planets are interesting for different reasons. Astrobiologists, however, are much more interested in the first category because rocky planets are probably the only planets that can support life. One needs to have a reasonably stable pressure-temperature regime in which life can originate, and this is not possible in the fully convective, semi-infinite atmosphere of a gas/ice giant planet. Rocky planets themselves are not all equally interesting to astrobiologists. Those too close to their parent star may be too hot for life to exist. Those too far from the star may only be able to support subsurface life, which would be difficult to detect remotely. Thus, astrobiologists are most interested in planets within the habitable zone (HZ) around their parent star within which liquid water is stable on the planetary surface. The frequency of planets within the HZs of main sequence stars has been studied recently using data from NASA's Kepler Space Telescope. This value is termed η_{Earth}. The value of η_{Earth} continues to change as Kepler data analysis proceeds, but it is likely between 0.1 and 0.5 for G, K, and M stars. The value of η_{Earth} depends on the HZ boundaries, and these continue to be refined as climate models improve. Other new work is being done on the topic of interpreting possible atmospheric biosignatures, such as the presence of O_2 in a planet's atmosphere. The talk will attempt to show where we are on all of these topics.

Modeling the emission of terrestrial planets with GCMs

Illeana GOMEZ-LEAL

Cornell University, Ithaca - USA

The emission of an exoplanet and its variations along the orbital motion carry a precious information about the climatic regime at work and the surface conditions. Investigating the links between the climate and the observables for such planets can yield new approaches to characterize terrestrial planets in future observations. We use a 3D general circulation model (GCM) to simulate the climate of a synthetic Earth and several terrestrial planets and study how the climate and the emission and the light curves planets depart from those of our planet. We show that the equilibrium temperature, the Bond albedo and the rotation period can in theory be retrieved from the light curve in all the modeled cases.

Composition, Structure and Formation of Low-Density Planets Within 0.5 AU of Their Star

Jack LISSAUER

NASA Ames Research Center, Moffett Field - USA

Kepler has discovered that tens of percent of sunlike stars possess one or more planets larger than Earth within 0.5 AU. Masses of dozens of small and mid-sized exoplanets have been measured using radial velocity or transit timing variations. Few transiting planets larger than 1.6 Earth radii are rocky. Rather, the planetary mass-radius diagram for planetary radius between 1.6 and 8 times that of Earth shows a tendency for mass to increase slowly with size. The scatter is larger than can be explained by observational errors and correlations with temperature, implying that the population is heterogeneous. Many Neptune-size planets have very low densities and must have a substantial fraction of their volumes occupied by hydrogen and/or helium. Models of the structure, growth and evolution of planets made of mixtures of rock and light gases will be presented and compared with observations of both individual bodies and of the characteristics of the population as a whole.

Discovering Earths and Super-Earths in the Solar Neighborhood with the Transiting Exoplanet Survey Satellite

George RICKER

Massachusetts Institute of Technology, Cambridge - USA

The Transiting Exoplanet Survey Satellite (TESS) will discover thousands of exoplanets in orbit around the brightest stars in the sky. In a two-year survey of the solar neighborhood, TESS will monitor more than 200,000 bright stars for temporary drops in brightness caused by planetary transits. This first-ever spaceborne all-sky transit survey will identify planets ranging from Earth-sized to gas giants, around a wide range of stellar types and orbital distances. TESS stars will typically be 30 - 100 times brighter than those surveyed by the Kepler satellite; thus, TESS planets will be far easier to characterize with follow-up observations. For the first time it will be possible to study the masses, sizes, densities, orbits, and atmospheres of a large cohort of small planets, including a sample of rocky worlds in the habitable zones of their host stars. Full frame images with a cadence of 30 minutes or less will provide precise photometric information for more than 20 million stars during observation sessions of several weeks. The brighter TESS stars will potentially yield valuable asteroseismic information as a result of monitoring at a rapid cadence of 2 minute or less. An extended survey by TESS of regions surrounding the North and South Ecliptic Poles will provide prime exoplanet targets for characterization with the James Webb Space Telescope (JWST), as well as other large ground-based and space-based telescopes of the future. TESS will issue data releases every 4 months, inviting immediate community-wide efforts to study the new planets. The TESS legacy will be a catalog of the nearest and brightest main-sequence stars hosting transiting exoplanets, which will endure as the most favorable targets for detailed future investigations. TESS is targeted for launch in 2017 as a NASA Astrophysics Explorer mission.

The PLATO 2.0 Mission

Heike RAUER

Institute of Planetary Research, DLR, Berlin - Germany

The PLATO Mission has been selected for ESAs M3 launch opportunity. PLATO will discover and bulk characterize extrasolar planets around hundreds of thousands of stars. With launch foreseen in early 2024, PLATO will follow the very successful space missions CoRoT and Kepler, as well as ESAs first small mission CHEOPS and NASAs mission TESS. PLATO will carry out high-precision, long-term photometric and astroseismic monitoring of up to a million of stars covering over 50% of the sky, and significantly increase the number of characterized small planets around bright stars in comparison to the previous missions. Its exquisite sensitivity will ensure that it detects hundreds of small planets at intermediate distances, up to the habitable zone around solar-like stars. PLATO will characterize planets for their radius, mass, and age. It will provide the first large-scale catalogue of well-characterized small planets at intermediate orbital periods, relevant for a meaningful comparison to planet formation theories and providing targets for future atmosphere spectroscopy. This data base of bulk characterized small planets will provide a solid basis to put the Solar System into a wider context and allow for comparative exo-planetology. The talk will provide an overview of the PLATO mission and its science goals.

Tuesday 30th June, morning chair: *Geoffrey MARCY*

Theoretical perspectives on super-Earths and mini-Neptunes

Invited review

Masahiro IKOMA

Dept. of Earth & Planetary Science, The University of Tokyo - JAPAN

Our Solar System contains no objects intermediate in mass between the Earth and Uranus. In contrast, beyond our Solar System, such objects called super-Earths (SEs) or mini-Neptunes (MNs) are much more common than gas giants, at least, in short-period orbits, according to transit observations by the Kepler space telescope. Thus, those objects must be a key for us to have unified understanding of the origins and evolutions of planetary systems and also know the uniqueness of our Solar System. The first two transiting super-Earths, CoRoT-7b and GJ1214b, already indicated the diversity of SEs/MNs. The bulk density of CoRoT-7b is as high (about 4 - 7 g/cm^3) as that of the Earth, so that the planet is likely to be rocky with a negligible amount of atmospheric gas. From the compositional point of view, the planet is just a big version of the Earth, which we could call a super-Earth. In contrast, the bulk density of GJ1214b is as low (about 1 - 2 g/cm^3) as those of Uranus and Neptune, so that the planet is likely to be icy or have a relatively massive H/He atmosphere. Thus, we might have to call the planet a mini-Neptune rather than a super-Earth.

Such diversity has been confirmed by subsequent discoveries of SEs/MNs with various bulk densities. The observed diversity of SEs/MNs with short orbital periods is qualitatively consistent with recent theories of planet formation, but is quantitatively still a mystery. The formatin of short-period SEs/MNs involve many processes complexly. Orbital migration is obviously needed to explain the proximity to their host stars. Giant collisions among protoplanets may occur, resulting in further growth after migration. Since orbital migration usually requires the presence of disk gas, the protoplanets may capture the surrounding disk gas to form H/He atmospheres. Furthermore, planets orbiting close to their host stars tend to receive intense stellar UV radiation, which leads to photoevaporative mass loss. In this talk, I will review theoretical predictions of diversity of SEs/MNs and discuss which ongoing and future observations are crucial for understanding the origins of SEs/MNs.

SPIRou : a nIR spectropolarimeter & high-precision velocimeter for the CFHT

Jean-François DONATI

IRAP, Université de Toulouse, FRANCE

SPIRou is a near-infrared (nIR) spectropolarimeter and high-precision velocimeter for the Canada-France-Hawaii Telescope (CFHT). SPIRou aims at becoming world-leader on two high-impact science topics, (i) the quest for habitable Earth-like planets around low-mass stars, and (ii) the study of low-mass star and planet formation in the presence of magnetic fields. In addition to these two main goals, SPIRou will be able to tackle many more key programs, from weather patterns of brown dwarfs to Solar system planet and exoplanet atmospheres, dynamo processes in fully-convective bodies, planet habitability and massive star formation. The science programs that SPIRou proposes to tackle are forefront, ambitious and timely - ideally phased in particular with complementary space missions like TESS and JWST. SPIRou is designed to carry out its science mission with maximum efficiency and optimum precision.

More specifically, SPIRou will be able to cover a wide simultaneous nIR spectral domain (0.98 - 2.35 μm), including the K band, at a resolving power of 73.5 K and to provide polarimetric capabilities, with a 15% average throughput and a radial velocity (RV) precision of 1m/s. Both the K band and the polarimetric capabilities are key assets for the two main science goals. Supported and funded by a large international team, SPIRou is currently in construction - with first light at CFHT planned for 2017.

The CHEOPS mission

David EHRENREICH

Observatoire de Genève - SUISSE

The Characterizing Exoplanet Satellite (CHEOPS) will be the first mission dedicated to search for transits by means of ultrahigh precision photometry on bright stars already known to host planets. By being able to point at nearly any location on the sky, this follow-up mission will provide the unique capability of determining accurate radii for a subset of those planets for which the mass has already been estimated from ground-based spectroscopic surveys. It will also provide precise radii for new planets discovered by the next generation transit surveys (such as NGTS or TESS). Focusing on Neptunes and super-Earths around bright stars, CHEOPS will moreover identify golden targets for detailed characterization with spectrographs equipping future large telescopes in space and on the ground. CHEOPS is the European Space Agency's first "small"-class mission as well as the next European exoplanet mission. It is scheduled for launch in 2017. I will present the science objectives and top-level requirements of the mission and provide an update on his current status.

New view on exoplanet transits: describing the granulation pattern with three-dimensional hydrodynamical simulations of stellar convection

Andrea CHIAVASSA

Laboratoire Lagrange, Observatoire de la Côte d'Azur, Nice - FRANCE

A potential complication to planet detection technique is caused by stellar surface inhomogeneities (due to the presence of stellar granulation, magnetic spots, dust, etc.) of the host star. Large efforts have been made in recent decades to use theoretical modelling of stellar atmospheres to solve multidimensional radiative hydrodynamic (RHD) equations in which convection emerges naturally. These simulations take surface inhomogeneities into account (e.g., granulation pattern) and velocity fields and are used to predict reliable observables. 3D RHD grid of simulations cover a substantial portion of the Hertzsprung-Russell diagram, including the evolutionary phases from the main sequence over the turnoff up to the red giant branch for low-mass stars. Modeling the transit light curves implies the importance to have a good representation of the background stellar disk. I will present how the RHD simulations are used to model the temporal fluctuations of the granulation pattern for different kind of stars and how this affect the depth, the ingress/egress causing fluctuations that have to be considered as an intrinsic incertitude, due to the stellar variability, on precise measurements of exoplanet transits of planets with small diameters. In this context, 3D RHD simulations are essential for a detailed quantitative analysis of the transits.

Twenty years of exploration of the giant planet population

Invited review

Magali DELEUIL

Laboratoire d'Astrophysique de Marseille - FRANCE

Easy to detect and apparently also to characterize, the giant population may seem well explored and understood. The advent of ultra high precision photometry which has largely open the domain of small size planets, has also focussed a large part of the scientific interest on this population which hold the promise of favorable conditions for life. However, after two decades of large surveys that have provided us with hundreds of giant planets, we are still far from being able to close their case, these discoveries raising new questions on their diversity, their mechanism of formation and their evolution. In this talk, we will review the main outcomes of these various observation programs and our current knowledge of giant planet populations, from the hot Jupiters to temperate and cold ones. Special attention will be given to the results achieved thanks to space-based missions, CoRoT and Kepler. These mission have revived old debates such as what can differentiate a planet and a brown dwarf. Combined to ground-based observations, they have also shed new light on their dynamical and physical properties, and have given the possibility to probe their atmosphere properties.

Dissipation in planar resonant planetary systems: implications of observed orbital configurations

Jean-Baptiste DELISLE

Observatoire de Genève - SUISSE

Using an analytical model, we study the dynamical evolution of two planets in mean-motion resonance undergoing dissipation. We focus on the long-term evolution of the period ratio. We first apply this model to the Kepler mission multi-planetary candidates (Delisle et al, 2012, 2014, Delisle & Laskar 2014). Indeed, close-in planetary systems detected by the Kepler mission present an excess of period ratios that are just slightly larger than some first order resonant values (2/1, 3/2). This feature occurs naturally when resonant couples undergo dissipation, such as tidal effect, that damps the eccentricities. We also apply our model to individual exoplanetary systems, and look how the current configuration of the planets constrains the dissipative forces they underwent in the past. This allows to put constraints on the nature (gaseous or rocky) of the planets (Delisle et al, 2014) since the tidal dissipation highly depends on their internal structure.

Refs.:
Delisle, Laskar, Correia, Boué, 2012, A&A, 546, A71
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Planets with two suns

Veselin KOSTOV

Dept. of Astronomy & Astrophysics, U. of Toronto - CANADA

Planets with two suns have long fascinated our imagination yet it was only recently that we were able to provide direct evidence of their existence. It was not until 2011 and the launch of NASAs Kepler mission that such circumbinary planets were unambiguously detected, for the first time, through their transits. I will review the current status of the field, then focus on transiting circumbinary planets. I will describe the detection methods and analysis tools required for their characterization, discuss the theoretical implications of their discoveries, and touch on the future prospects in the field.

The high precision search for northern Neptunes and Super-Earths with SOPHIE

Benjamin COURCOL

Laboratoire d'Astrophysique de Marseille - FRANCE

The Doppler velocimetry is crucial and efficient technique in exoplanet detection and characterization, used for both surveys and transit follow-up. Improvements have allowed a few stabilized spectrographs to detect exoplanets with minimum masses as low as $1\,M_\oplus$ gradually paving the area of Neptune-like and Super-Earths exoplanets. With the need for surveys aiming at low mass planets and the high number of upcoming transit missions around bright stars (NGTS, CHEOPS, TESS), the demand for high precision RV measurements will continue to significantly increase in the next years. The SOPHIE spectrograph, located on the 1.93-m telescope of Observatoire de Haute Provence, has been improved in June 2011 with the implementation of octagonal-section fibers. This optimization phase led to a gain in RV precision, now close to 2 m/s, and to the subsequent beginning of surveys aiming for low-mass exoplanets. We present here first results of this subprogram which include the detection of a warm Neptune, the identification of new promising candidates, updated parameters of some known low-mass exoplanets and the limit of detection in our sample. We discuss the implications of these results when transitioning to the low mass planet regime. We will also discuss the synergy of our SOPHIE programs with the incoming CHEOPS mission as well as the ongoing improvement of SOPHIE to ultimately reach the 1m/s precision.

The close (0.02 to 2.5 AU) giant planet population around Main-Sequence A - F stars

Simon BORGNIET

Institut de Planétologie et d'Astrophysique de Grenoble - FRANCE

The radial velocity (RV) and transit methods have led to thousands of giant planet discoveries for twenty years, dramatically improving our knowledge of giant exoplanets. However, many open questions remain regarding different aspects of giant planet formation. RV and transit surveys have mainly focused on solar-like FGK stars, and more recently on low-mass M-dwarf stars, while A - F early type stars have been mostly avoided. The impact of the host star mass on the system's properties is still difficult to test. We present here the combined results of two RV surveys carried since 2005 on the HARPS and SOPHIE spectrographs on a sample of about 230 A - F, Main-Sequence stars more massive than the Sun. We will review the Giant Planet detections, detection limits, and will provide the derived occurence rates of close-in Giant Planets around such stars.

Constraining the Kepler-11 Planet Masses with Radial Velocities

Lauren WEISS

University of California, Berkeley - USA

The six transiting planets of Kepler-11 have all been found to have ultra-low densities through N-body dynamical analysis of the transit timing variations (TTVs) of the planets. Numerically reproducing TTVs has become a new method for solving the masses of planets, but this method is susceptible to certain dynamic degeneracies: the planet eccentricity is degenerate with the planet mass, and perturbations caused by non-transiting planets could be misattributed to the transiting planets. Furthermore, the masses of planets characterized by TTV analysis are systematically two times lower than the masses (including non-detections) reported by radial velocity (RV) analysis for planets of the same radius. We address the discrepancy between the TTV- and RV- determined planet masses by measuring the RVs of Kepler-11 at opportunistic times, as determined by the ephemerides of the transiting planets. We obtained 17 RVs of Kepler-11 system with Keck/HIRES over the summer of 2014. From our RVs only, we place a 3-sigma upper limit on the masses of the Kepler-11 planets of 2x their nominal masses. Thus, we demonstrate that the RVs are consistent with the ultra-low mass scenario determined by the TTVs. We use the simplectic N-body integrator TTVFAST to jointly model the RVs and Q1 - Q17 TTVs of Kepler-11, deriving new and improved planet masses and densities for the five inner planets and constraining the mass of the outermost planet better than TTVs can do alone. The consistency of the TTVs and RVs in the Kepler-11 system bodes well for N-body simulations of TTVs for other Kepler systems that are too faint for RV follow-up.

Structure and evolution of transiting giant planets: a Bayesian homogeneous determination of orbital and physical parameters

Aldo Stefano BONOMO

Observatorio Astrofisico di Torino, Turin - ITALY

We present a Bayesian homogeneous determination of orbital and physical parameters of a large sample of 209 giant transiting planets with masses between 0.1 and 25 M_{Jup} and precision on mass estimates better than 30%. We analyze new high-precision radial velocities for about forty of them with the HARPS-N TNG spectrograph to improve and, in some cases, to revise the measure of their orbital eccentricity and to put constraints on the presence of long-period companions. Moreover, from updated determinations of orbital eccentricities we estimate the modified tidal quality factors of giant planets and search for possible correlations between inflated radii and non-zero eccentricities. Our comprehensive study:

1) allows for improved understanding of orbital evolution and migration scenarios for giant planets and, in general, the architecture of planetary systems with Jupiter-sized planets,

2) provides the much needed benchmark statistics for thorough investigations of the diversity of giant planet densities and interior structures.

First results from the Multi-site All Sky CAmeRA, MASCARA

Ignas SNELLEN

Leyden Observatory - THE NETHERLANDS

Since late 2014, the first station of the Multi-Site All Sky CAmeRA is operational on La Palma monitoring the sky at V = 4 - 9. Its main purpose is to find the brightest transiting planet systems in the sky. In this talk, I will describe the project and present the first results.

Next Generation Transit Survey (NGTS)

Philipp EIGMUELLER

Institute of Planetary Research, DLR, Berlin - GERMANY

The Next Generation Transit Survey project (NGTS) is a new ground-based transit survey aimed at detecting exoplanets of the size of Neptune and smaller around bright and cool stars. It consists of twelve robotic telescopes with an aperture of 20 cm, each equipped with a 2K×2K NIR sensitive detector and a field-of-view of 8 square degrees. NGTS builds upon the experience of past and current surveys. The instrument is installed at the ESO Paranal observatory in order to benefit from the excellent observing conditions and follow-up synergy with the VLT and E-ELT. NGTS will survey brighter stars than the CoRoT and Kepler mission, and will therefore find the brightest exoplanets of Neptune and super-Earth size, providing the prime targets for exoplanet characterization. Early 2015 NGTS had "First Light" and is currently in commissioning. We present the project and first results from the commissioning data.

On the origin of stellar spin-orbit angle in extrasolar systems

Gwenaël BOUÉ

IMCCE, Observatoire de Paris - FRANCE

Two different paths may lead to hot Jupiters: migration in the protoplanetary disk and dynamical interaction with other planets or with a stellar binary companion. These two scenarios predict different stellar spin-orbit angle distributions. Hence, several works have been dedicated to the study of spin-orbit measurements in order to disentangle the two scenarios. However, other mechanisms like chaotic star formation or magnetic interaction with the disk are also susceptible to produce spin-orbit misalignments. In this talk, I will present a method to lift the veil on the origin of stellar obliquity and to get information on planetary systems early evolution.

First radial velocity observation of a binary system detected by microlensing

Isabelle BOISSE

Laboratoire d'Astrophysique de Marseille - FRANCE

The gravitational microlensing technique allows the discovery of exoplanets around stars distributed in the disk of the galaxy towards the galactic bulge. However, the alignment of two stars that led to the discovery is unique in a human life and cannot be reobserve. Moreover, the target host is very faint and other techniques are often needed to characterise the target and then, its companion(s). In 2013, Gould et al. published the predicted radial-velocity curve of a binary system, OGLE-2011-BLG-0417, discovered and characterised from a microlensing event (Shin et al. 2012). We used the UVES spectrograph mounted at the ESO-VLT to derive precise radial-velocity measurements of OGLE-2011-BLG-0417. We will show our nine radial velocities on the $V = 18$ host, propose a refinement of the analysis of the microlensing event, and discuss how the radial velocity measurements on targets with microlensing observations could be use in the future to refine the microlensing models.

Characterization of Microlensing Planetary Systems by AO imaging

Akihiko FUKUI

Okayama Astrophysical Observatory, NAOJ - JAPAN

Microlensing is a powerful tool to probe wide-mass-range exoplanets just outside the snow line, where gas-giant planets are considered to efficiently form. Drawing a precise mass distribution of planets by microlensing is thus important to test several planetary-formation models. However, about a half of the microlensing events do not show parallax effect, which is necessary to derive the absolute planetary and host-stars masses from the microlensing light curves alone. In such a case, extracting the fluxes from the host stars by adaptive-optics (AO) imaging with large telescopes plays an important role to supplementary constrain the masses of the planetary systems. I present one such example, OGLE-2012-BLG-0563Lb, which is a Saturn-mass planet orbiting an M dwarf. We successfully detect the light from its host star by using the 8.2-m Subaru telescope and constrain the masses without parallax signal. In addition, I show that the second-epoch AO observation with JHK bands will be able to constrain the metallicity of the host star.

Metallicity distribution for planet-hosting stars from Penn State - Torun Centre Planet Search (PTPS)

Beata DEKA-SZYMANKIEWICZ

Torun Centre for Astronomy - POLAND

One of key questions in planet formation theory is the relation between planetary and stellar host properties. Studies of such relations require precise determinations of such stellar parameters like luminosities, masses, radii, rotation velocities and chemical abundances (or metallicity). For a conclusive analysis all those parameters have to be available for total samples of stars searched for planets. One of stellar parameters related to giant planet occurrence appears to be stellar metallicity. The planet occurrence rate and stellar host metallicity relation is well establihed for main-sequence dwarfs (Fischer & Valenti. 2005). Furthermore, as frequently stated, dwarfs stars with planets tend to have higher metallicity than the same type stars without planets (Fischer & Valenti 2005; Ghezzi et al. 2010). Two alternate scenarios may be responsible for this relation. Either planets form preferentially in high-metallicity environments (Fischer & Valenti 2005) or the increased metallicity of planetary systems hosts is a result of material accretion onto the star (self-pollution) during planet formation phase (Gonzalez 1997). Expanding the planet occurrence vs. stellar metallicity relation to other stars than dwarfs poses a problem, however.

Metallicity of planet-hosting giants stars ([Fe/H] = - 0.06 dex) is predominantly lower than for dwarf stars with planets while planet-hosting subgiant stars have on average metallicity similar to dwarfs with planets ([Fe/H] of about + 0.11 dex) (Ghezzi et al. 2010). On the other hand, Reffert et al. (2015) found for their sample of G and K type giant stars a planet-metallicity relation similar to that for main-sequence stars shown by Fischer & Valenti (2005). Clearly the planet occurrence rate vs. stellar host metallicity relations still requires more attention for stars beyond the main sequence.

Within the Penn State-Torun Centre for Astronomy Planet Search (PTPS) about 1000 stars, mostly giants and sugbgiants are monitored for radial velocity variations (Niedzielski et al. 2007; Niedzielski & Wolszczan 2008). In parallel to planet search, stellar parameters for all stars in the sample are being studied in detail. Zielinski et al. (2012) presented absolute radial velocities, basic atmospheric parameters, luminosities, masses and radii for 348 stars from the Red Clump subsample. Adamow et al. (2014) presented Li abundances and rotation velocities for these stars.

In forthcoming papers the Giants and Subgiants (Niedzielski et al. - in prep) and Evolved Dwarfs (Deka-Szymankiewicz et al. - in prep.) subsamples will be presented in detail. Here we present metallicity distributions for the three subsamples and compare them with metallicity distribution for all 17 PTPS detected planetary systems.

Frequency of Exoplanets Beyond the Snow Line from 6 Years of the MOA Survey

David BENNETT

University of Notre Dame - USA

We present the first statistical analysis of exoplanet signals from microlensing survey data. 1471 high quality microlensing events from the 2007 - 2012 observing seasons. Planetary signals were observed for 22 of these events, while 2 of these events have possible planetary signals that could also be modeled as microlensing by a stellar binary system. We find a exoplanet frequency consistent with, but lower than, previous results from microlensing follow-up groups. We also explain how our analysis can be expanded to measure the exoplanet frequency as a function of host star mass and Galactocentric distance using exoplanet and host mass determinations from microlensing parallax measurements and detection of the lens star with high angular resolution follow-up observations.

From Super-Earths to Giant Planets

Michel MAYOR

Observatoire de Genève - SUISSE

A systematic radial velocity survey, carried out in the Southern sky with the HARPS spectrograph, provides some interesting statistical results. One of the most striking feature is the discontinuity of statistical properties for planets with masses smaller or bigger than 30 Earth-masses.

Reevaluation of the Possibility and Impact of Layered Convection: Application to the Radius Anomaly of Hot Jupiters

Hiroyuki KUROKAWA

Earth-Life Science Institute, Tokyo Institute of Technology - JAPAN

Observations have revealed that a significant number of hot Jupiters have anomalously large radii compared with the theoretical model of planets composed of hydrogen and helium. Layered convection induced by compositional inhomogeneity in their interiors has been proposed to explain the inflated radii of hot Jupiters. The compositional inhomogeneity possibly inhibits large-scale-overturning convection and forms small-scale-layered convection which is separated by diffusive interfaces. A pioneering study (Chabrier & Baraffe, 2007) assumed the presence of the layered convection in the interiors of hot Jupiters and demonstrated that its effect on the delayed contraction is sufficient to reproduce the inflated radii. However, the layers form in a limited parameter range determined by the temperature and mean-molecular-weight gradients. We perform an evolutionary calculation with a self-consistent treatment of the convection regimes to reevaluate the possibility and impact of the layered convection. It is shown that the possibility of the layered convection is limited in the case of continuous gradient of heavy-element abundance. The convection regime is the overturning convection in their young stages (< 1 Gyr). Also we demonstrate that the impact of the layered convection depends significantly on the layer thickness. Extremely thin layers are necessary to reproduce the inflated radii of hot Jupiters. Our results suggest that it may hard to explain the radius anomaly only by this mechanism at least in the case of the continuous gradient of heavy-element abundance.

Hot-Jupiter Inflation due to Deep Energy Deposition

Sivan GINZBURG

Racah Institute of Physics, The Hebrew University, Jerusalem - ISRAEL

Some extrasolar giant planets in close orbits (hot Jupiters) exhibit larger radii than that of a passively cooling planet. The extreme irradiation these hot Jupiters receive from their close in stars creates a thick isothermal layer in their envelopes, which slows down their convective cooling, allowing them to retain their inflated size for longer. This is yet insufficient to explain the observed sizes of the most inflated planets. Some models invoke an additional power source, deposited deep in the planet's envelope. We present an analytical model for the cooling of such irradiated, and internally heated gas giants. We show that a power source, parameterized by intensity and deposition depth, is equivalent to an enhanced stellar irradiation. We derive scaling laws for the cooling rate of the planet, its central temperature, and radius. These scaling laws can be used to estimate the effects of various mechanisms involving energy deposition on sizes of hot Jupiters.

On the structure and evolution of planets and their host stars - effects of various heating mechanisms on the size of giant gas planets

Mutlu YILDIZ

Dept. of Astronomy & Space Science, Ege University, Izmir - TURKEY

It is already stated in the previous studies that the radius of the giant planets is affected by stellar irradiation. The confirmed relation between radius and incident flux depends on planetary mass intervals. In this study, we show that there is a single relation between radius and irradiated energy per gram, per second (l-), for all mass intervals. There is an extra increase in radius of planets if l- is higher than 1100 times energy received by the Earth. This is likely due to dissociation of molecules. The tidal interaction as a heating mechanism is also considered and found that its maximum effect on the inflation of planets is about 15%. We also compute age and heavy element abundances from the properties of host stars, given in the TEPCat catalogue (Southworth 2011). The metallicity given in the literature is as [Fe/H]. However, the most abundant element is oxygen, and there is a reverse relation between the observed abundances [Fe/H] and [O/Fe]. Therefore, we first compute [O/H] from [Fe/H] by using observed abundances, and then find heavy element abundance from [O/H]. We also develop a new method for age determination. Using the ages we find, we analyse variation of both radius and mass of the planets with respect to time, and estimate the initial mass of the planets from the relation we derive for the first time. According to our results, the highly irradiated gas giants lose 5% of their mass in every 1 Gyr.

Two hot Jupiters from WASP with siblings

Marion NEVEU-VANMALLE

Observatoire de Genève - SUISSE

In the swarm of multiple extrasolar planetary systems, hot Jupiters have for a long time been thought to be "only children". While recent studies demonstrated that many of them have distant companions (e.g. Knutson et al. 2014), only a handful were found to have "siblings" at moderate separations, with a full orbital period observed. Formation theories have demonstrated that hot Jupiters migrated to their current orbits from beyond the snow line (Rafikov 2006). Two mechanisms can cause the migration of giant planets: interaction with the gas disc or interaction with a third body (planetary or stellar). The fraction of each mechanism is still under debate. Finding planetary companions to the known hot Jupiters is one of the keys to determine which mechanism took place. We have conducted a long-term radial velocity survey of the WASP planets with the spectrograph CORALIE, in order to search for additional companions. I will present two recently discovered "big siblings" of hot Jupiters, located at 1 AU from their parent star. Recognizing magnetic cycles is essential when searching for long-term radial velocity variations. While the emission in the Calcium band is the preferred indicator for activity, it is difficult to extract from moderate resolution and low signal-to-noise spectra. On the other hand, the emission in the H alpha band is easy to measure, in particular from the CORALIE spectra. I will describe how the Hα index can be used to identify magnetic cycles.

Theoretical perspectives on giant planets

Invited review

Adam SHOWMAN

Lunar and Planetary Lab., Tucson - USA

The giant planets and brown dwarfs, broadly defined, exhibit a diverse range of behaviors that continue challenge our understanding. In many ways, giant planets are less well understood than either stars or terrestrial planets, which bound giant planets on the high- and low-mass ends, respectively. Here, I will review recent observations and theoretical advances that address the “grand challenge” of dynamically understanding these fascinating objects. Major observational advances are occurring simultaneously on three main fronts, comprising, respectively, the “local” giant planets of our solar system, the highly irradiated hot Jupiters, and brown dwarfs and directly imaged giant planets. Our solar system giant planets have atmospheric circulations dominated by numerous east-west (zonal) jet streams, cloud bands, and vortices; major effort is currently being spent to understand the structure and mechanisms driving these circulations. Brown dwarfs and directly imaged giant planets show extensive evidence of dynamics via their cloud layers, surface patchiness, chemical disequilibrium, and other signatures. These observations raise numerous puzzles about the nature of the circulation on brown dwarfs and its relationship to that of Jupiter and Saturn. Finally, for the hot Jupiters, a wealth of observations constrain the day-night temperature differences, vertical temperature structure, circulation, and cloudiness. The presumed tidal locking of close-in planets implies a novel – and still poorly understood – climate regime of permanent dayside heating and nightside cooling. Collectively, these diverse objects span over four orders of magnitude in intrinsic heat flux and incident stellar flux, and two orders of magnitude in gravity and rotation rate – thereby placing strong constraints on how the circulation of giant planets (broadly defined) depend on these parameters.

I will review the specific theoretical puzzles and advances in each of these fields, and attempt to highlight aspects where dynamical unity emerges, as well as aspects where the diverse conditions lead to divergent outcomes.

Convection and Mixing in Giant Planet Evolution

Allona VAZAN

Tel Aviv University - ISRAEL

The primordial internal structures of gas giant planets are unknown. Often giant planets are modeled under the assumption that they are adiabatic, convective, and homogeneously mixed, but this is not necessarily correct. We present a self-consistent calculation of convective transport of both heat and material as the planets evolve. We discuss how planetary evolution depends on the initial composition and its distribution, whether the internal structure changes with time, and if so, how it affects the evolution. Our work demonstrates that the primordial internal structure of a giant planet plays a substantial role in determining its long-term evolution and that giant planets can have non-adiabatic interiors. These results emphasize the importance of coupling formation, evolution, and internal structure models of giant planets self-consistently.

Hydrogen-Water Mixtures in Giant Planet Interiors Studied with ab initio Simulations

François SOUBIRAN

University of California, Berkeley - USA

With the extraordinary discovery of more than 1700 confirmed exoplanets and even more candidates from the Kepler survey, the need for more accurate structure and evolution models becomes very relevant. One important issue for gas and ice giant planets is to determine the behavior of hydrogen-water mixtures in their envelope. It is currently unknown whether a planet contains a dense, hot steam atmosphere or a water ocean that is well separated from a hydrogen atmosphere. Laboratory measurements demonstrated the molecular hydrogen and water phase separate at low pressure and temperature. Recently, computer simulations predicted that water and metallic hydrogen form a homogeneous mixture at pressure of 10 megabars and 3000 K [Wilson & Militzer, ApJ 745, 54 (2012)]. The intermediate pressure regime that is of interest for giant planets in our solar system and sub-Neptune exoplanets has not been explored. We present results from ab initio computer simulations in combination with Gibbs free-energy calculations. We determine the stability of hydrogen-water mixtures from 2 to 70 GPa and from 1000 to 6000 K, and discuss the consequences for the giant planet interiors. Our findings may have implications for the heat transfer and the distribution of other compounds like ammonia in giant planets envelopes.

Beta Pic b, physical properties and possibility of transits

Alain LECAVELIER des ÉTANGS

Institut d'Astrophysique de Paris - FRANCE

The intermediate-mass star β Pictoris is known to be surrounded by a structured edge-on debris disk within which a gas giant planet was imaged at a distance of 8 - 10 AU. The physical properties of β Pic b are inferred from broad- and narrow-band 0.9 - 4.8 μm photometry and low-resolution (R $\simeq$ 35 - 39) J-band spectrum of the planet. The extracted spectrum of β Pic b is similar to those of young L1 - 1.5 + 1 dwarfs. The 0.9 - 4.8 μm photometry and spectrum are reproduced for $T_{eff} = 1650 \pm 150\,K$ and a $\log g \leq 4.7$ dex. For the most recent system age estimate (21 ± 4 Myr), the bolometric luminosity and the constraints on the dynamical mass of β Pic b are only reproduced by warm- and hot-start tracks. These initial conditions may result from an inefficient accretion shock and/or a planetesimal density at formation higher than in the classical core-accretion model.
The astrometric measurements constrain the orbit of β Pic b. In addition, in 1981 the star β Pictoris showed strong and rapid photometric variations, possibly due to a transiting giant planet. The observed motion of β Pic b is consistent with an inferior conjunction in 1981, and it could be the transiting planet proposed to explain the photometric event observed at that time. We will describe the sets of orbits which are compatible with astrometric measurements and the transit of 1981, with the estimates of the possible dates for the next transits which could take place as early as 2017 or 2018. If confirmed, the observation of the transit of a young planet 21 million years old, passing in front of a 3^{rd} magnitude star, would be of prime interest.

Co-author: Mickaël BONNEFOY (Institut de Planétologie et d'Astrophysique de Grenoble)

Thursday 2nd July, morning chair: *Michel MAYOR*

A hike across the desert

Amaury TRIAUD

University of Toronto - CANADA

Low mass stars, brown dwarfs and hot Jupiters have similar radii. For a fairly narrow size range ($\sim$0.7 to 2 Jupiter radii) Nature has produced objects covering nearly three orders of magnitude in mass (between 0.2 and 200 Jupiter masses). This is of particularly importance for transit surveys which are mostly sensitive to size. Those same surveys are also heavily biased towards proximity to the central, most luminous object. This how ground-based transit surveys have primarily found hot Jupiters. Those planets can be hotter and bigger than the smallest Hydrogen burning stars. My talk will explore the transition from planet to brown dwarf, to low mass star, and how one can compare them to one another. I will show similarities, but also distinctions between these different classes of objects. I will present the results of observations from the WASP survey including an independent and mostly unbiased confirmation of the brown dwarf desert. We also looked at the spin-orbit angle distributions, as measured from the Rossiter-McLaughlin effect, between both ends of that desert. They are very different. In addition, our observations discovered systems containing both planets and brown dwarfs that can make us wonder about their formation process. Brown dwarfs, hot Jupiters and low mass stars have similar fluxes. I will show how colour-magnitude diagrams can be constructed to compare these objects and how they can used for observations. Their compilation unveiled a new diversity for exoplanets: they show a wider variety of atmospheric properties than their brown dwarf cousins. With enough time I will push into the realm of circumbinary architectures, and how they can expand the discussion on the distinction between planets, brown dwarfs and low mass stars, but also how they can be exploited to study stellar and planetary formation, to investigate cold planetary atmospheres and help the search for and eventual characterisation of habitable-zone rocky worlds.

Brown dwarf detections through gravitational microlensing

Clément RANC

Institut d'Astrophysique de Paris - FRANCE

A number of brown dwarf companions to stars have been discovered by radial velocities, transits, direct imaging and microlensing. Recent discoveries have confirmed the ability of gravitational microlensing to detect brown dwarfs in very different contexts, from solitary objects to brown dwarfs orbiting low-mass stars, including a population of low-mass brown dwarfs hosting planets in a very tight orbit. Compared to other detection techniques, microlensing allows the discovery of exoplanets and brown dwarfs at distances from the Earth greater than a few kiloparsecs, up to the Galactic Bulge, which would have been hard to detect with other methods.

I present the specificity of the microlensing method to detect brown dwarfs, discuss the different detections made so far, and present a new brown dwarf detection orbiting a solar-type star. This microlensing detection is presented in the broader panorama of other inhabitants of the brown dwarfs desert detected by other methods.

Exploring the giant planet - brown dwarf connection with astrometry

Johannes SAHLMANN

European Space Astronomy Centre, ESA, Madrid - SPAIN

Modern surveys of isolated brown dwarfs and of extrasolar planets around Sun-like stars reveal a continuous mass distribution across the deuterium-burning mass limit. This challenges the mass criterion sometimes used to distinguish between these objects and calls for methods that can trace the different formation paths instead. Astrometric measurements are a way forward because they yield both the orbital parameters and the planet mass. We will show results from ground- and space-based astrometric surveys that explore the giant planet - brown dwarf connection. These include the systematic determination of true masses for substellar objects found in radial-velocity surveys and the discovery of brown dwarfs orbited by very low-mass substellar objects. Finally, we will outline how the Gaia astrometry mission will help to describe the substellar demographics.

Radial velocity search for long-period exoplanets and brown dwarfs

Javiera REY

Observatoire de Genève - Suisse

A number of brown dwarf companions to stars have been discovered by radial velocities, transits, direct imaging and microlensing. Recent discoveries have confirmed the ability of gravitational microlensing to detect brown dwarfs in very different contexts, from solitary objects to brown dwarfs orbiting low-mass stars, including a population of low-mass brown dwarfs hosting planets in a very tight orbit. Compared to other detection techniques, microlensing allows the discovery of exoplanets and brown dwarfs at distances from the Earth greater than a few kiloparsecs, up to the Galactic Bulge, which would have been hard to detect with other methods. I will present the specificity of the microlensing method to detect brown dwarfs, discuss the different detections made so far, and present a new brown dwarf detection orbiting a solar-type star. I will present this microlensing detection in the broader panorama of other inhabitants of the brown dwarfs desert detected by other methods.

Possible astrometric discovery of a substellar companion to the closest binary brown dwarf system WISE J104915.57-531906.1

Henri BOFFIN

European Southern Observatory, Garching Germany

We have astrometrically monitored over a period of more than a year the two components of the brown dwarf system WISE J104915.57-531906.1, the closest one to the Sun. Our astrometric measurements - with a relative precision at the milli-arcsecond scale - allow us to detect the orbital motion and derive more precisely the parallax of the system, leading to a distance of 2.020 ± 0.019 pc. The relative orbital motion of the two objects is found to be perturbed, which leads us to suspect the presence of a substellar companion around one of the two components. We also perform VRIz photometry of both components and compare with models. We confirm the flux reversal of the T dwarf and present additional data on the binary.

A new transiting brown dwarf from the CoRoT sample and the frequency of close-in brown dwarfs

Szilárd CSIZMADIA

Institute of Planetary Research, DLR, Berlin GERMANY)

We report the detection of a rare transiting brown dwarf with a mass of $62\,M_{Jup}$ and a radius of $1.2\,R_{Jup}$. It orbits a G9V star on a 5.82 days period, slighly eccentric (e = 0.07) orbit, thus it is a new member of its class in the so-called brown dwarf desert. The orbital period of the brown dwarf is very close (within 3%) to the 3:2 resonance with the rotational period of the star which may be important test case for tidal evolution studies. Using the CoRoT-sample,the true frequency of brown dwarfs close to their host stars ($P < 10\,d$) is estimated to be 0.18% (0.0018 brown dwarf/star for FGK dwarfs within the range $P < 10\,d$) which is about six times smaller than the frequency of hot Jupiters in this period range.

Giant planets and brown dwarfs : Who's Who ?

Invited review

Gilles CHABRIER

Centre de Recherche Astrophysique de Lyon - FRANCE

In this talk, I will examine the various channels suggested for the formation of giant planets and brown dwarfs, respectively, and confront these scenarios to existing observational constraints. In a second part of the talk, I will explore the observational diagnostics enabling us to distinguish between these two types of astrophysical bodies in their overlapping mass regime.

Difficulties with a Planet and Brown Dwarfs Who's Who

Jean SCHNEIDER

LUTH, Observatoire de Paris, Meudon - FRANCE

The constitution of an exoplanet/brown dwarf Who's who requires two prerequisites:

1) the choice of a very "definition" of an exoplanet,

2) once a definition has been chosen, the decision to include or not a given candidate as "confirmed" into the Who's who.

I will present several difficulties, deeply conceptual or only technical, in these two steps. I will show how the Extrasolar Planets Encyclopaedia proposes to solve (imperfectly) these problems.

Brown dwarfs and super-Jupiters in the nearest OB association to the Sun: Upper Scorpius

Nicolas LODIEU

Instituto de Astrofisica de Canarias, Tenerife - SPAIN

Upper Scorpius is part of the nearest OB association to the Sun, located at 145 pc, with an age of 5 - 10 Myr. Our group has studied in depth the low-mass, substellar, and planetary-mass populations of Upper Sco during the past decade. We identified the first brown dwarfs with masses below 20 Jupiter masses which we confirmed spectroscopically. We also derived the low-mass and substellar mass function of the full association. Recently, we conducted a deep ZYJ survey (Z = 22 mag, Y = 21.5 mag, J = 20.5 mag) of 13.5 square degrees in the central region of the association with VISTA/VIRCAM. We identified 67 bona-fide photometric and astrometric members with masses in the 5 - 30 Jupiter mass range according to state-of-the-art models. In this contribution, we will summarise our work and present the photometric selection of the coolest member candidates identified in our deep survey. We will also present VLT/Xshooter near-infrared spectroscopy of these candidates, discuss their physical properties, and the implication for the substellar and planetary regime mass function.

Searching for Scatterers: High Contrast Imaging of Young Stars with Wide-Separation Planetary Mass Companions

Marta BRYAN

California Institute of Technology, Pasadena - USA

We have conducted a deep angular differential imaging survey with NIRC2 at Keck in search of close-in substellar companions to a sample of seven systems with confirmed planetary mass companions (PMCs) on extremely wide orbits (> 100 AU). Over the past decade, adaptive optics direct imaging searches for young, hot gas giant planets have revealed a new population of companions with orbital separations of hundreds of AU and masses near or at the deuterium burning limit. Thus far, 12 PMCs have been confirmed, nearly all of which are less than 10 Myr old. These wide-separation PMCs pose significant challenges to all three plausible formation mechanisms: core accretion plus scattering, disk instability, and turbulent fragmentation. We test the possibility that the observed planets formed closer in and were scattered out to their present day locations by looking for other massive bodies interior to their present-day orbits.

<u>**Thursday 2nd July, afternoon chair:**</u> *Heike RAUER*

Observations of Brown Dwarfs

Invited review

Kevin LUHMAN

Penn State University, University Park - USA

I will review observations that may be useful in distinguishing between brown dwarfs and giant planets, including their mass functions, binary properties, and accretion disk signatures. I will also discuss data for brown dwarfs that can provide tests of models of planetary atmospheres, such as the spectral energy distributions the youngest and coldest brown dwarfs.

Brown dwarfs and planemos in nearby star forming regions

Aleks SCHOLZ

School of Physics & Astronomy, U. of St Andrews - UNITED KINGDOM

We present results from SONYC, an extremely deep survey of nearby star forming regions with the goal to characterise the substellar mass function. The survey is based on imaging, complemented by proper motions, and followed by multi-object spectroscopy. It has discovered dozens new brown dwarfs in NGC1333, Rho Oph, Upper Scorpius, Cha-I and Lupus. Through SONYC and similar surveys the substellar mass function is now well characterised down to 5 - 10 Jupiter masses. It is found that star formation process typically generates about 2 - 5 brown dwarfs per 10 stars. We see tentative evidence for regional differences in the efficiency of brown dwarf formation, suggesting that environments with higher object density may produce a larger fraction of very-low mass objects. Our results indicate that free-floating planetary mass objects ("planemos") are rare and represent the low-mass tail of the stellar mass function.

Observing free-floating brown dwarfs and transiting exoplanets with JWST/NIRSpec

Catarina ALVES de OLIVEIRA

European Space Astronomy Centre, ESA, Madrid - SPAIN

The James Webb Space Telescope (JWST) and its suite of instruments will have an unprecedented combination of sensitivity and spectral coverage. In this contribution, we focus on one of these instruments, the near-infrared spectrograph NIRSpec. NIRSpec will cover the 0.6 - 5.3 μm spectral domain with 3 ranges of spectral resolution (R $\simeq$ 100, 1000 and 2700). In its multi-object spectroscopy mode it will be able to obtain spectra of up to 100 astronomical objects simultaneously by means of a configurable array of micro-shutters. It also features an integral field unit and a suite of slits for high contrast spectroscopy of individual objects, including an aperture spectroscopy mode dedicated to the characterization of transiting exoplanets. We will present an overview of the instrument capabilities and simulations that showcase the observations of free-floating brown dwarfs and transiting exoplanets.

Red giants with brown dwarfs companions

Andrzej NIEDZIELSKI

Torun Centre for Astronomy - POLAND

The planetary mass increase for more evolved hosts seems to be one of the most prominent features of known planetary systems. An average giant star hosts a companion about twice as massive than in the case of a dwarf, and a bright giants companion is 3 times more massive, on average. Certainly, that is not an observational bias caused by RV jitter present in giants as companions below Jupiter mass can be easily detected around those stars (for instance BD+48 738 b, Gettel et al. 2012). Assuming an average value of sin i, companions to bright giants are, on average, at the brown dwarf planet borderline (see also Mitchell et al. 2013). It is rather obvious that such an amount of mass cannot be accreted by a giant planet during its hosts RGB evolution (Duncan & Lissauer 1998). I will present a few more examples of such intriguing red giants with brown dwarf companions recently detected within our ongoing PennState-Torun Planet Search (Niedzielski et. al. 2007, Niedzielski et al. 2015) and review more general properties of such systems.

Luminosities of young directly-detectable exoplanets

Gabriel-Dominique MARLEAU

Max Planck-Institut für Astronomie, Heidelberg - GERMANY

Motivated by direct-detection surveys such as SPHERE and GPI, we present a grid of cooling tracks for gas giants obtained by coupling our planetary evolution code to state-of-the-art BT-Settl atmospheres of various metallicities, providing self-consistently calculated magnitudes. The grid's main coordinates are the mass M and the initial entropy S_i of a planet or low-mass brown dwarf, enabling the use of arbitrary initial conditions ("cold", "warm" or "hot starts") to test different formation outcomes. In this spirit, we also show how to place joint constraints on the mass and initial entropy of an object from its luminosity and age, taking observational uncertainties into account in a Bayesian framework.

Can brown dwarfs survive on close orbits around convective stars?

Cilia DAMIANI

Institut d'Astrophysique Spatiale, Orsay - FRANCE

The lack of massive companions orbiting close to FGKM stars, the so-called "brown dwarf desert", offers a useful observable way to distinguish between planets and brown dwarfs. However, the mechanisms responsible for this distinction are still not elucidated, as is the question of the formation and evolution of brown dwarfs. Most of the discovered short-period brown dwarfs companions are observed orbiting around F-type stars. This led some authors to advance the hypothesis that brown dwarfs could not survive in close orbit around stars with important convective envelopes. The tides excited by the massive companion and the progressive spin-down due to magnetic braking would lead to the reduction of the semi-major axis and the eventual engulfment in the host star. We present here the results of a study of the stability of the tidal equilibrium states of a binary system under the constraint of the angular momentum loss of the host due to its wind. We show that on close orbits the system can enter into a stationary state, where the loss of the star's angular momentum due to the wind is compensated by the tidal torque. For massive companions, we show that this stationary state can be maintained over tens of Gyr. This delays significantly the final engulfment into the host, and prove that stars with convective enveloppe are capable of harbouring massive companions in close orbits. Therefore, the origin of the brown dwarf desert is more likely due to inefficient formation processes rather than the quick engulfment of the companion into the star.

Current status of the Sigma Orionis substellar mass function

Karla PEÑA RAMIREZ

Instituto de Astrofísica, PUC, Santiago - CHILE

We will present our current knowledge of the stellar and substellar mass function (19 $M_\odot$ through 5 M_{Jup}) of the young (3 Myr), nearby (352 pc), solar metallicity cluster Sigma Orionis. Using the broad band filters (ZYJHKs) in the magnitude interval J = 13 - 21 mag (completeness at J = 21.0 mag, Z = 22.6 mag and 10 M_{Jup}) combined with Spitzer/IRAC (3.6 and 4.5 μm) and optical images (I band) from our archives we have identified over 200 cluster low mass members candidates in most of the cluster area (> 70%). The 18% of the sources identified would have masses below 13 M_{Jup} according to theoretical models. An ongoing spectroscopic characterization of the cluster planetary-mass population is also presented. This by means of OSIRIS/GTC, ISAAV/VLT and FIRE/LCO low-resolution spectra (700 - 980 nm, R ∼ 200; 1.09 - 1.42 μm, R ∼ 500; 0.80 - 2.51 μm, R ∼ 400). Around the 40% of the sources in the planetary mass regime show youth features that confirms their cluster membership. If confirmed as bona-fide cluster members, their masses would range from 5 through 13 times the mass of Jupiter. Because these data and the spectra available in the literature cover more than 50% of the Sigma Orionis planetary-mass population, we will be able to set strong constrains on the cluster planet-mass function.

Searching for bona-fide proto-brown dwarfs

Aina PALAU

Centro de Radioastronomia y Astrofisica, Michoacán - MEXICO

The formation of brown dwarfs remains a highly debated field of current astrophysics. Several mechanisms have been proposed, such as ejection from fragmented massive disks or multiple systems, and the formation of dense cores of very low Jeans masses through gravo-turbulent fragmentation. In order to distinguish among the different scenarios, it is necessary to characterize brown dwarfs in their earliest stages of formation, what we call here "proto-brown dwarfs". In this talk, I will present the results of a project aimed at searching for 'bona-fide' proto-brown dwarfs. In particular, I will show a deeply embedded $\sim 35\,\mathrm{M}_{Jup}$ brown dwarf candidate, IC348-SMM2E, which is driving a molecular outflow, is associated with a rotating envelope, and presents a Spectral Energy Distribution similar to that of Class 0 protostars. In addition, I will present four proto-brown dwarf candidates associated with thermal radiojets, again comparable to the radiojets associated with low-mass protostars. Altogether suggests that the formation of brown dwarfs, at least for these cases, takes place as a scaled-down version of low-mass stars, as predicted by the gravo-turbulent fragmentation scenario.

Hunting for binaries with X-Shooter spectra

Elena MANJAVACAS

Max Planck-Institut für Astronomie, Heidelberg - GERMANY

The determination of the brown dwarf binary fraction may contribute to the understanding of the substellar formation mechanisms. Unresolved brown dwarf binary systems may be revealed through their peculiar spectra or the discrepancy between optical and near-infrared spectral type classification. We aimed to identify brown dwarf binary candidates, and to test whether BT-Settl 2014 atmospheric models reproduce the physics in the atmospheres of these objects. We obtained medium-resolution spectra of 22 peculiar brown dwarfs in the optical and the near-infrared using X-Shooter at the Very Large Telescope. To find binaries spanning the L - T boundary, we used spectral indices and we compared the selected candidates to single spectra and synthetic binary spectra. We also used synthetic binary spectra with components of same spectral type, to determine the sensitivity of the method to this class of binaries. From the best fit to the BT-Settl 2014 models to the observed spectra, we derived the atmospheric parameters of the single objects and identify which spectral features the models are unable to reproduce. We selected six possible candidates to be combination of L plus T brown dwarfs. All candidates, except one, were better reproduced by a binary spectra than by a single spectrum. Two other binary candidates were rejected as they did not show the expected overluminosity in the color-magnitude diagram. We found that we are not able to identify binaries with components of similar spectral type. The best matches to the BT-Settl models gave a range of effective temperatures between 950 K (T7) and 1900 K (L6.5), a range of gravities between 4.0 and 5.5. Some of the best matches corresponded to supersolar metallicity.

Pupil masking, a tool to understand planetary formation

Sylvestre LACOUR

LESIA, Observatoire de Paris, Meudon - FRANCE

Aperture masking is a niche technique to observe at high angular resolution and high contrast. This unique observational window allowed important discoveries, including bright spots in the gap of transition disks. The explanations for the flux vary, from young embedded planets to dust scattering in inclined disk. We will give a review of the results obtained by the technique, focusing on several recent discoveries around T Cha, LkCa15, IRS48, and HD142527.

Euclid Legacy Science on Brown Dwarfs

Eduardo MARTIN

Centro de Astrobiologia, Madrid - SPAIN

The Euclid space mission will deliver a wide area survey and a deep survey of unprecedented image quality in 4 different passbands from 0.5 to 2 microns, and near-infrared slitless spectra. Three years ago our teams proposal for ultra cool dwarf science with Euclid was selected by ESA. Since then we have participated in the Euclid Science Team and in this presentation we will present our current plans for brown dwarf science with this space telescope.

Friday 3rd July, morning chair: *Ignas SNELLEN*

Observations of exoplanet atmospheres from super-Earths to hot Jupiters

Invited review

David SING

Astrophysics Group, University of Exeter - UNITED KINGDOM

A variety of techniques are now able to detect and characterise a wide variety of exoplanets from Jupiter down to Neptune and Super Earth masses. Through transmission, emission, and phase curve spectroscopy of transiting planets with HST and Spitzer in particular, a great deal of detailed characteristics are now being learned about exoplanet atmospheres. With perhaps hundreds of such planets to characterise in the reasonably near future thanks to new surveys, a new opportunity is beginning to perform comparative exoplanetology. In this talk I will review the techniques used, highlight some of the major results and discuss a few of the major outstanding scientific issues.

Evaporating atmospheres: from hot-Jupiters to super-Earths

Vincent BOURRIER

Observatoire de Genève - SUISSE

Atmospheric escape has been detected through transit observations of hot Jupiters like HD209458b and HD189733b as a strong absorption in the ultraviolet lines of their host stars. Observations in the Lyα line of neutral hydrogen have been used to probe their extended exosphere, shaped by radiation pressure or stellar wind interactions, while observations in the line of neutral magnesium have been shown to probe lower altitudes in the exosphere/thermosphere transition region. Theoretical studies indicate that the extension of the atmosphere arises from the intense stellar X-ray and extreme ultraviolet energy input into the lower thermosphere, leading to moderate escape rate for hot Jupiters. However, smaller mass planets such as mini-Neptunes or super-Earths with a large gaseous envelope could be significantly affected by evaporation, leading in extreme cases to the formation of rocky planetary remnants. I will compare the upper atmospheric state of all exoplanets that have been looked for evaporation so far, from the hot Jupiter HD209458b to the super-Earth 55 Cnc e, including the recently observed warm-Neptune GJ436b.
I will show how observations of these planet transits have been used to retrieve both atmospheric and stellar properties, and study the impact of evaporation on a planet atmosphere and its evolution.

Four Hot Jupiters with Robustly Oxygen-Rich Compositions (C/O < 0.9)

Björn BENNEKE

California Institute of Technology, Pasadena - USA

Measurements of the bulk metallicities and carbon-to-oxygen ratios of hot Jupiters present an unprecedented opportunity to probe the formation, evolution, and migration histories of giant planets. Here, I present the main conclusions from a comprehensive atmospheric retrieval study of HST transmission spectra with detected near-IR molecular absorption features. I analyze the spectra using the newly developed self-consistent atmospheric retrieval framework, SCARLET. The new framework directly derives posterior probability distributions of the planet's metallicity, carbon-to-oxygen ratio (C/O), and cloud properties by combining self-consistent modeling of the atmospheric chemistry and physics with the robust Bayesian statistics of modern atmospheric retrieval techniques. The main finding is that the C/O ratios of all at least four hot Jupiters are robustly below 0.9. Recent suggestions of low water abundances and $C/O > 1$ cannot be confirmed if the presence of clouds and hazes is considered in the atmospheric modeling. I will discuss implications for the formation of hot Jupiters. Towards the end, I will give a short overview and early results from our ongoing, unprecedented 124-orbit HST program to survey super-Earth exoplanets.

Thick High-Altitude Clouds on an Extremely Inflated Hot Jupiter

Zachory BERTA-THOMPSON

Massachusetts Institute of Technology, Cambridge - USA

Clouds abound on exoplanets, yet the interpretation of their physical properties has often been limited by the relatively low signal-to-noise with which they have been detected. The super-inflated hot Jupiter WASP-94Ab provides a unique opportunity to probe exoplanet clouds through transmission spectroscopy. The WASP-94 system offers:

a) magnified transmission signals due to the planet's large atmospheric scale height,

b) the potential to yield low measurement noise due to a bright host star and a perfect nearby comparison star,

c) an easy-to-observe close physical analog for Kepler-7b, the first exoplanet with a measured cloud map.

We present observations of the 400 - 1000 nm transmission spectrum of WASP94Ab, definitively showing the presence of high-altitude clouds in its atmosphere. We understand the noise sources in our measurements down to the photon-noise limit of the 6.5-m Magellan Clay telescope with which they were taken, and the precision of our measurements rivals that of the Hubble/STIS transmission spectra of HD189733b and HD209458b. We discuss the implications of these observations in the contexts of both the known exoplanet population and the predicted plethora of nearby transiting exoplanets soon to be found by TESS.

Exoplanet Atmospheres at High Spectral Resolution

Matteo BROGI

University of Colorado, Boulder - USA

After only two decades from the first detection, we know today about 2,000 planets orbiting stars other than the Sun (exoplanets). Among the observing techniques for investigating their atmospheres, ground-based high-resolution ($R > 20{,}000$) spectroscopy has recently excelled in delivering robust molecular detections and estimating their relative abundances. The key aspect of this technique is the ability to resolve molecular bands into the individual lines, and to detect their Doppler shift due to the planet orbital motion, complementing traditional measurements of stellar radial velocities. I will review the major breakthroughs achieved in recent years, among which are the first atmospheric detections for non-transiting planets, and the unprecedented measurements of their true masses and orbital inclinations. I will present current efforts focusing on constraining the atmospheric composition and on measuring the planet rotational rates. Finally, I will focus on future prospects of ground-based, high-resolution spectroscopy, including the characterization of Earth-like planets and the identification of possible biomarkers.

First results from a four-year survey of exoplanet atmospheres using Gemini/GMOS

Catherine HUITSON

University of Colorado, Boulder - USA

Hot Jupiters are an important link between terrestrial planets and brown dwarfs. The study of their atmospheres reveals insights into exoplanet formation and migration, as well as enabling the study of dynamics and chemistry under unique conditions. With low densities and large radii, transiting hot Jupiters are also the most amenable to characterization today, providing lessons for future study of smaller planets. We report from the first multi-semester survey program dedicated to transmission spectroscopy using a ground-based multi-object spectrometer (MOS) in the visible. Our 4-year survey focussed on 9 hot Jupiters for which the wavelength dependent transit depths were measured with Gemini/GMOS. In total, 37 transits have been secured, with each exoplanet observed on average during four transits. This repeatability allows for a high spectrophotometric precision (200 - 500 ppm / 10 nm) and for a reliable estimate of the uncertainties. We present the first results from this survey, the challenges faced by such an experiment, and the lessons learnt for future instruments. With precisions in many cases equal to space-based observations, our survey is paving the way for future exoplanet characterization with ground-based MOS.

C/O or not C/O? Chemical fingerprinting of the birthplaces of exoplanet and brown dwarf companions

Taisiya KOPYTOVA

Max Planck - Institut für Astronomie, Heidelberg - GERMANY

The formation mechanism and formation location of exoplanets and brown dwarfs in circumstellar disks is still intensely debated. The two main scenarios for for formation of sub-stellar companions in circumstellar disks are gravitational instability (GI) and core accretion (CA). Based on observational studies of exoplanet systems, it seems that massive giant planet and brown dwarf companions form at large (> 40 AU) separations while less-massive planets originate closer-in. However, various migration mechanisms can affect present-day observed positions of sub-stellar companions, which complicates the picture. A way out is chemical fingerprinting. As carbon and oxygen have different condensation temperatures, the absolute (and relative) amounts of gaseous carbon and gaseous oxygen change with disk radius. Hence, the C/O ratio might provide the crucial hint for identifying the correct formation scenario of exoplanets and brown dwarf companions. However, the C/O ratio might also be subject to various degeneracies and uncertainties. For instance, the classical search for the best fit to models might result in a set of unphysical parameters, or to reveal several models that describe observation equally well. In this case, the use of a sequential (i.e. "Bayesian") approach should give more reliable results. In addition, a solar-like abundance for host stars of exoplanets and brown dwarfs is often assumed, which is not always justified. Therefore, independent estimates for abundances of hosts stars must be provided. In this work, we present abundance measurement for host stars and their directly imaged sub-stellar companions. We attempt to atmospheric models from different groups to our observed spectra of sub-stellar companions. We also discuss various ways of applying the sequential approach for identifying physical parameters using spectra. C/O or not C/O? That is the question.

HST Transmission Spectral Survey: observations, data analysis and results

Nikolay NIKOLOV

Astrophysics Group, University of Exeter - UNITED KINGDOM

Over the past decade, observations of transits have revolutionized our understanding of exoplanet atmospheres thanks in large part to spectroscopy with the Hubble and Spitzer Space Telescopes. In this talk I will discuss the goals, overall methodology and some of the main results from a Large HST optical and near-IR spectral survey (P.I. David Sing) of eight hot Jupiters spanning a wide range of temperatures. We type each planet atmosphere by a comparative analysis with hot Jupiter models of cloudy, hazy and cloud-free atmospheres. Together with previous HST observations, this program is showing scattering by aerosols and absorption from water and alkali metals across the target range implying a significant diversity in exoplanet atmospheres.

Investigating close-in exoplanet atmospheres with optical phase curves

Antonio GARCIA MUÑOZ

ESTEC, European Space Agency, Noordwijk - THE NETHERLANDS

Visible-wavelength, broadband photometry of spatially unresolved exoplanet+star systems is setting key constraints on various aspects of close-in exoplanet atmospheres (geometric albedos, temperatures, super-rotation) through the analysis of the planet phase curves. To date, this is the approach that has been enabled for a handful of exoplanets by COROT, Kepler and MOST [1-3]. In the incoming years, CHEOPS, PLATO and TESS will greatly expand the number of available optical phase curves, thus allowing for comparative studies amongst a larger planet sample. A theoretical framework to investigate such phase curves and the information contained in them is still missing. We have set out to establish such a framework, and to make the connection between the fundamental properties of exoplanet atmospheres (cloud spatial distribution, optical depth, cloud particle scattering properties, scale height) and the observed phase curves. In the presentation, we will discuss which atmospheric properties could be constrained from optical phase curves, and emphasize possible degeneracies between key atmospheric parameters. We will comment on the role of the planet phase curve in the fitting of the planet+star system light curve. We use our results to explore the parameter space that future exoplanet GCMs equipped with cloud prediction capacities will need to consider. We also comment on the added value of multi-color photometry that could be delivered by future space missions.

Refs.
[1] Angerhausen et al., 2014, arXiv: 1404.4348
[2] Esteves et al., 2013, ApJ, 772, 51
[3] Demory et al., 2013, ApJL, 776, L25

The ARIEL space mission

Jean-Philippe BEAULIEU

Institut d'Astrophysique de Paris - FRANCE

ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) is a dedicated 1-m class survey space telescope submitted to ESA-M4 for a potential launch in 2024. ARIEL will observe a large number (~ 500) of warm and hot transiting gas giants, Neptunes and super-Earths around a range of host star types using transit spectroscopy in the 1.95 - 7.8 μm spectral range. ARIEL target planets hotter than 600 K in order to take advantage of their well-mixed atmospheres which should show minimal condensation and sequestration of high-Z materials and thus reveal their bulk and elemental composition (especially C, O, N, S, Si). This is unlike the planets in our own Solar System where there is a cold trap in their deep atmosphere/interior for species such as H_2O, CH_4, NH_3, SiO, $CO_2 \ldots$, which condense at much colder temperatures. Observations of hot exoplanets can therefore enable the understanding of the early stage of planetary and atmospheric formation during the nebular phase and the following few millions years. In this way, ARIEL will provide a truly representative picture of the chemical nature of the planets and relate this directly to the type and chemical environment of the host star.

We will present the ARIEL science case and mission concept, and underline its unique niche in the era of JWST and ELT. Planetary science stands at the threshold of a revolution in our knowledge and understanding of our place in the Universe: just how special are the Earth and our Solar System? It is only by undertaking a comprehensive spectral survey of exoplanet atmospheres in a wide variety of environments that we can hope to answer this critical question. ARIEL is the only proposed facility that can provide all the necessary observations.

Friday 3rd July, afternoon chair: *Eduardo MARTIN*

Transitions in Efficiency of Heat Redistribution in hot Jupiter Atmospheres

Thaddeus KOMACEK

Lunar & Planetary Lab, U. of Arizona, Tucson - USA

What controls heat regulation in planetary atmospheres? How is heat redistributed over a range of equilibrium temperature, atmospheric composition, and potential frictional drag strengths? Examining full-phase light curves of close-in extrasolar giant planets, or "hot Jupiters", there is a trend of increasing dayside-nightside flux differences (equivalent to a lowered heat redistribution efficiency from day to night) with increasing equilibrium temperature. Here we utilize atmospheric circulation modeling to examine this trend and identify that the transition from high to low heat redistribution efficiency is controlled by adjustment due to gravity waves. The key parameter mediating dayside-nightside temperature differences is the amplitude of radiation, with a second-order effect from potential frictional drag. We present an analytic scaling theory that can explain the observed heat redistribution efficiency trends of decreasing redistribution efficiency with increasing radiative forcing. This redistribution efficiency increases with pressure for all of our numerical simulations, a robust result which is replicated in our pressure-dependent theory. Additionally, our scaling theory enables prediction of characteristic horizontal and vertical wind speeds given an observed dayside-nightside temperature difference. Hence, this analytic work can aid in explanation of hot Jupiter observations, enabling understanding of the basic circulation of a given planet from an observed phase curve.

Transmission spectral properties of cloud condensates

Hannah WAKEFORD

Astrophysics Group, University of Exeter - UNITED KINGDOM

Clouds play an important role in the atmospheres of planetary bodies. It is expected that, like all the planetary bodies in our solar system, exoplanet atmospheres will also have substantial cloud coverage, and evidence is mounting for clouds in a number of hot Jupiters.

To better characterise planetary atmospheres, we need to consider the effects these clouds will have on the observed broadband transmission spectra. Here we examine the expected cloud condensate species for hot Jupiter exoplanets and the effects of various grain sizes and distributions on the resulting transmission spectra from the optical to infrared, which can be used as a broad framework when interpreting exoplanet spectra. We note that significant infrared absorption features appear in the computed transmission spectrum, the result of vibrational modes between the key species in each condensate, which can potentially be very constraining. While it may be hard to differentiate between individual condensates in the broad transmission spectra, it may be possible to discern different vibrational bonds, which can distinguish between cloud formation scenarios, such as condensate clouds or photochemically generated species. Vibrational mode features are shown to be prominent when the clouds are composed of small sub-micron sized particles and can be associated with an accompanying optical scattering slope.

These infrared features have potential implications for future exoplanetary atmosphere studies conducted with JWST, where such vibrational modes distinguishing condensate species can be probed at longer wavelengths.

Condensation processes in substellar atmospheres

Derek HOMEIER

Landessternwarte, ZAH, Heidelberg - GERMANY

Cloud formation has been recognised as an important physical process in ultracool atmospheres since the earliest observations of brown dwarfs, as well as being a visible phenomenon in the solar system gas giants. More recently the importance of condensates at lower temperatures has been revealed both observationally and from theoretical modelling, with mounting evidence for the signature of water ice clouds in the very coolest Y dwarf observed to date. Similarly, clouds are a dominant feature in the atmospheres of extrasolar planets from hot Jupiters to comparatively cool Neptune- and super-Earth class planets, where cloud opacity up to high altitudes has been confirmed from transmission spectroscopy. Realistic modelling of such multi-layered cloud structures, reaching with decreasing temperature from iron and silicate over alkaline to water and ammonia ice grains, is therefore essential for understanding the chemistry of these atmospheres. Condensation and depletion further affects molecular and atomic opacities that dominate in particular the optical spectra.
I will present modelling results from an analytic cloud model covering dynamic properties of the entire stellar and brown dwarf sequence as well as effects specific to planets with significant irradiation.

Characterizing exoplanet atmospheres using atmospheric circulation models

Tiffany KATARIA

Astrophysics Group, University of Exeter - UNITED KINGDOM

As observations of exoplanet atmospheres have grown in number and complexity, spanning a larger wavelength range at ever-higher spectral resolution, they have provided unprecedented constraints for general circulation models. Like observations of variable brown dwarfs, these datasets allows us to place constraints on the wind and temperature structure as a function of height, and help quantify the extent to which dynamical mechanisms (e.g. magnetic effects, chemical mixing) play a role in the circulation. In this talk, I will present three-dimensional (3D) coupled radiation-circulation models for a range of exoplanets that have been heavily characterized by ground- and space-based observations. These targets include those from our groups large Hubble Space Telescope (HST) program, for which multiple observations have been obtained using the Space Telescope Imaging Spectrograph (STIS) and Wide Field Camera 3 (WFC3).

I will show how the theoretical observations generated from our circulation models, including phase curves, transmission and emission spectra, can be compared to observations to place constraints on the planets atmospheric composition, temperature structure and potential presence of haze or clouds. Taken together, these models have explored exoplanet circulation over a wide range of planetary properties, including eccentricity, orbital distance, rotation rate, mass, gravity, composition, metallicity, and stellar flux.

I will discuss the trends that have been observed in these studies, and the potential to probe further dynamical regimes with next-generation instruments.

Vertical mixing and fingering convection in cool brown dwarf atmospheres

Pascal TREMBLIN

Astrophysics Group, University of Exeter - UNITED KINGDOM

Numerous projects devoted to the detection and characterization of exoplanets and brown dwarfs, both based on indirect (NGTS, CHEOPS, TESS, PLATO) and direct methods (SPHERE, GPI, ELT), will deliver over the next decades exquisite data which require accurate and performant numerical tools for their interpretation. We present the development of a 1D atmospheric code ATMO that solves the radiative/convective equilibrium in order to produce high resolution spectra of hot jupiters and brown dwarfs. The code is modular and includes line by line radiative transfer with the following opacity sources: CAI H_2-H_2, H_2-He, H_2O, NH_3, TiO, VO, K, Na, CO, CH4 (STDS and the new line list from ExoMol). The code takes into account both equilibrium and out-of-equilibrium chemistry of 110 neutral species including C, H, N, O elements by using the minimization of Gibbs energy at equilibrium and the kinetics of a chemical network of 1000 reactions (Venot et al. 2012). The out-of-equilibrium chemistry includes vertical mixing and photo-chemistry.
We present first results on the atmospheres of hot jupiters (e.g. HD209458b), brown dwarfs (T and Y), and the first steps toward the coupling of the chemistry with a 3D global circulation model, the unified model, developed at the UK Met-office for the modeling of Earth climate.

Cloudy and cloudless Hot Jupiters

Vivien PARMENTIER

Laboratoire Lagrange, Observatoire de la Côte dAzur, Nice - FRANCE

Clouds seem ubiquitous in Hot Jupiters atmospheres. Different hints for clouds for different planets have been detected. In the transmission spectra, clouds seem to flatten the signal at large wavelength and provide a Rayleigh scattering signature at small wavelength. Clouds turn the thermal emission spectra into a blackbody shape, reducing our ability to detect molecular feature. They lower the thermal flux emitted from the nightside of the planet. They shape the albedo spectrum of the dayside of the planet. More recently, the presence of a shifted maximum in the Kepler light curve of a handful go planets has been interpreted as the signature of a partially cloudy dayside and points toward the presence of a transition between cloudy and cloudless planets. Hot Jupiters are intrinsically 3D objects and global circulation models are necessary to understand the physical processes shaping the spatial distribution of clouds. This is fundamental to link observations that probe different regions of the planet. Using a a grid of global circulation models, I investigate the expected thermal structure and 3D cloud coverage of hot Jupiters, its observational consequences and constrain the possible composition of those exotic clouds.

POSTER ABSTRACTS

1

Brown dwarf search in Penn State - Torun Centre Planet Search (PTPS) - the JOTA project

Michalina ADAMCZYK

Torun Centre for Astronomy - POLAND

Brown dwarfs (BD) are ambiguous objects with masses in the approximate 13 - 80 Jupiter masses range. They occupy the gap between planets and stars: having sufficient mass to burn deuterium but not enough to burn hydrogen in their inner cores. They are found mostly as isolated objects but also as a companions to stars (Rebelo et al. 1995; Nakamija et al. 1995). Given the ease of detecting objects of BD's masses with the high precision radial velocity (RV) surveys, it is rather surprising that only few tens of BD have been found so far in massive RV planet searches and only 10 of them orbiting giant stars (Jones et al. 2015). That BD paucity has led to the brown dwarf desert concept (Marcy & Butler 2000). Although most RV surveys are focused on detecting companions to main-sequence stars, the fraction of BDs in relatively close-in orbits around giants stars seems to be higher as compared to less evolved host stars (Mitchell et al. 2013). The difference between predicted and the actual detection rate may be attributed to the host star mass or to the effect of stellar evolution. Within the ongoing PTPS Planet Search (Niedzielski et al. 2007) we have been monitoring RV variation in approximately 1000 stars. A subsample of 150 mostly evolutionary advanced stars, with low mass companions in BD's mass range is currently monitored for RV variations with CAFE at CAHA 2.2m and with Fies at 2.6 NOT. I present motivation and first results of a brown dwarf search in PTPS sample - the JOTA project.

2

On the non-habitability of water-rich planets

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In this contribution, we consider the effect of high water fraction on the (non-)habitability of exoplanets, and show that above a certain amount of water, high pressure water ice forms at the bottom of the global ocean, which prevents the operation of the CO_2 cycle. We also show how this translates to a maximum radius above which a planet cannot be habitable.

3

New line profiles of potassium perturbed by molecular hydrogen for very cool brown dwarfs

Nicole ALLARD

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The cooling sequence of brown dwarfs has now been observationally characterised well beyond the transition from T to Y, or corresponding to effective temperatures down to 250 - 500 K. Such objects are directly comparable to massive giant planets (super-Jupiters) around a Gyr of age or older, and the closest analogues of Jupiter-mass planets at intermediate ages. Due to strong molecular and quasi-molecular absorption (CIA) at longer wavelengths, among their spectral features best characterised from the ground are the NIR flux peaks around 1 micron, actually emerging from deep photospheric layers at temperatures around 1000 K and pressures of 10 - 100 bar. The opacity in the red optical to near IR region under these conditions is dominated by the extremely pressure-broadened wings of the alkali resonance lines, in particular the K[I] resonance doublet at 0.77 micron. Modelling their line shapes requires detailed calculations of the collisional broadening for perturber densities that reach several 10^{19} H_2 molecules/cm^3 even in Jupiter-mass planets and exceed 10^{20} for super-Jupiters and older Y dwarfs.
In this poster, we evaluate K - H_2 collisional profiles for temperatures and densities appropriate for modeling very cool brown dwarf atmospheres. Laboratory measurements are used to validate new ab initio molecular potentials which support the spectral line profile theory. We also report the dependence of line parameters on temperature, and compare with previous calculations obtained from pseudo-potentials.

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4

Regaining the FORS: optical ground-based transmission spectroscopy of the exoplanet WASP-19b with VLT+FORS2

Henri BOFFIN

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Since a few years, the study of exoplanets has evolved from being purely discovery and exploratory in nature to being quite quantitative. In particular, transmission spectroscopy now allows the study of exoplanetary atmospheres. Such studies rely heavily on space-based or large ground-based facilities, as one needs to perform time-resolved, high signal-to-noise spectroscopy. The very recent exchange of the prisms of the FORS2 atmospheric diffraction corrector on ESOs Very Large Telescope should allow us to reach higher data quality than was possible before. With FORS2, we have obtained the first optical ground-based transmission spectrum of WASP-19b, with a 20 nm resolution in the 550 - 830 nm range. This data set represents the highest resolution transmission spectrum for this planet obtained to date. We detect large deviations from planetary atmospheric models in the transmission spectrum redward of 790 nm, indicating the presence of additional sources of opacity not included in the current atmospheric models for WASP-19b, or additional, unexplored sources of systematics. Nonetheless, this work shows the new potential of FORS2 to study the atmospheres of exoplanets in greater detail than has been possible so far.

5

The closest known flyby of a star to the Solar System

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Passing stars can perturb the Oort Cloud, triggering comet showers and potentially extinction events on Earth. We combine velocity measurements for the recently discovered, nearby, low-mass binary system WISE J072003.20-084651.2 ("Scholz's star") to calculate its past trajectory. Integrating the Galactic orbits of this $\sim 0.15\,M_{\odot}$ binary system and the Sun, we find that the binary passed within only ~ 52 kAU (0.25 parsec) of the Sun, i.e. within the outer Oort Cloud. This is the closest known encounter of a star to our solar system with a well-constrained distance and velocity. Previous work suggests that flybys within 0.25 pc occur infrequently (~ 0.1/Myr). We show that given the low mass and high velocity of the binary system, the encounter was dynamically weak. Using the best available astrometry, our simulations suggest that the probability that the star penetrated the outer Oort Cloud is $\sim 98\%$, but the probability of penetrating the dynamically active inner Oort Cloud (< 20 kAU) is $\sim 1E^{-4}$. While the flyby of this system likely caused negligible impact on the flux of long-period comets, the recent discovery of this binary highlights that dynamically important Oort Cloud perturbers may be lurking among nearby stars.

6

Temperature constraints on the coldest brown dwarf known

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Nearby isolated planetary mass objects are beginning to be discovered, but their individual properties are poorly constrained because their low surface temperatures and strong molecular self-absorption make them extremely faint. We observed the field containing WISE0855-0714, located ~ 2.2 pc away, with HAWK-I at the VLT in the Y band. WISE0855-0714 was not detected in our Y-band images, thus placing an upper limit on its brightness to $\mathrm{Y} > 24.4$ mag at 3-sigma level, leading to $\mathrm{Y} - [4.5] > 10.5$. Combining this limit with previous detections and upper limits at other wavelengths, WISE0855-0714 is confirmed as the reddest BD detected, further supporting its status as the coldest known brown dwarf. We applied spectral energy distribution fitting with collections of models from two independent groups for extremely cool BD atmospheres leading to an effective temperature of $\mathrm{T}_{eff} < 250$ K.

7

Obliquities measured with SOPHIE

Isabelle BOISSE

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The observations of the transit with spectroscopic measurements permit to detect an anomaly, called Rossiter-MacLaughlin effect. This detection allow the measure of the obliquity of the system. Nowadays, almost a hundreds of systems are characterised, with some are found with an angle between the stellar equator plane and the orbital plane projected on the sky significantly different from zero, or even with retrograde orbits contrarily on the Solar System. Such observations are not expected if the planet has migrated within the proto-planetary disk. It may result from dynamical effects involving the existence of additional companions in the system, such as Kozai cycles or planet-planet scattering. We will report ten observations of RM effects with SOPHIE at OHP. First obliquities are derived for 4 objects, refined values are given for 5 planets and one is not detected. For 3 of them, the transits parameters are refined thanks to photometric observations.

8

Disentangling planetary and starspots features

Giovanni BRUNO

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We present an analytically-based method to disentangle the signature of a planet from that of starspots on the surface of a magnetically active star. The approach is based on a model developed by Montalto et al. (2014), which calculates the normalized photometry from a given coverage of starspots on a limb-darkened transited star. We complete it with the calculation of the time evolution of the spots, following the prescription of Kipping (2012). We include this model in a consistent Markov chain Monte Carlo software, developed at LAM for the combined fit of photometric and spectroscopic data of transiting planets. Our code aims to be comparable in speed to a code for normal transit fit. We apply it to two canonical examples of transiting planets around active stars, CoRoT-7b and CoRoT-2b. We use the brightness variations in the whole light curve to explore the correction of the activity and further measure the respective transit depths.

9

Searching for extrasolar planets around cool stars with GIANO

Ilaria CARLEO

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Among the cool stars, M-dwarfs are becoming increasingly popular among the current programs aimed at searches for extrasolar planets. They are by far the most numerous class of stars in the Galaxy so that any reliable estimate of the global frequency of planets can not be derived excluding them. Even more crucially, the habitable zone is located close to the star for low-mass stars thanks to their low luminosity. Planet-search radial velocity surveys at optical range cannot be performed for the the late M, the most numerous class of M-dwarfs, because they are too faint at that wavelengths. The late-M are instead bright in the near infrared (NIR), the working range of GIANO, the new IR spectrograph available at the TNG, able to provide accurate radial velocity measurements. Actually no other IR instruments have the GIANO's capability to cover the entire NIR wavelength range. Furthermore the impact of stellar activity that often is quite strong for M-dwarfs is greatly reduced in the NIR with respect to the optical.
We have developed an ensemble of IDL procedures to measure high precision radial velocities on GIANO spectra acquired during the Science Verification run, using the telluric lines as wavelength reference. The method is applied to various targets with different spectral type, from a K0V to an M8 star. Mainly depending on H magnitude we reached different dispersions: for a H magnitude of about 5 we obtain an rms scatter of $\sim 10\,\mathrm{m/s}$, while for a H magnitude of about 9 the standard deviation goes up to $\sim 100\,\mathrm{m/s}$.

10

Study of low mass stars in eclipsing binary systems by radial velocity with PARAS

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Eclipsing Binary systems serve as an effective tool for the precise determination of masses and radii of both the components. Single lined eclipsing binary systems via radial velocity technique give us a unique opportunity to study the substellar candidates and low mass end of the main sequence as companions to brighter primaries. Despite a large number of low mass stars present in our galaxy, masses and radii for these stars are still not determined at higher accuracies, primarily due to their fainter magnitudes in visible band. Radii for stars less massive than Sun are known to be 10% smaller theoretically than observed and temperatures are 5% higher. A high-resolution echelle spectrograph,PARAS (Physical Research Laboratory Advanced Radial-velocity Abu-sky Search), working at a resolution of 67 000, coupled with the Physical Research Laboratory Mt. Abu 1.2-m telescope (India) is used for making observations of primary stars of F, G and K spectral type.

One of the programs with our high resolution spectrograph PARAS operational in the wavelength regime 3800 - 6800 $\AA$ is to look for candidates having secondaries in the low massive end of the main sequence and hunt for brown dwarfs in the speculative brown dwarf desert. Follow-up spectroscopy observations with PARAS of two eclipsing binary candidates (1SWASPJ234318.41+295556.5 and SAO 106989) from SuperWasp ground-based photometry consortium has led to interesting discoveries. First, one is that of a star which is just above the hydrogen burning limit and lies close to the boundary of L dwarfs/M dwarfs. The primary comprises of a K-dwarf having a mass of $0.786\,M_{\odot}$ with a temperature of $\sim 5000\,K$. The secondary is possibly the lightest M dwarf (M9 spectral type) discovered with a mass of $0.092 \pm 0.02\,M_{\odot}$ in a slight eccentric orbit of 0.1. The period of 16.9 days determined by PARAS is crucial for this system as SuperWasp photometry misinterpreted the period to be 4.24 days due to poor sampling of photometry data. RV measurements of second target source SAO 106989 (F7 primary star) indicates the presence of $0.25\ M_{\odot}$ secondary (mid-M dwarf) in a period of 4.35 days and an eccentricity of 0.25. The period obtained by PARAS for this system matches well with the observed period by SuperWasp team. The results from these two systems are highlighted in the presentation.

11

Beta Pictoris transit with PICSAT

Lester DAVID

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The idea of the PICSAT demonstrator is to spatialize a 3U CubeSat using a 35 mm aperture and a very sensitive single pixel avalanche photodiode. The scientific objective of this mission would be to study the β Pictoris b transit occuring in summer 2017. To guarantee photometric precision and CubeSat stabilisation, the Attitude Determination and Control System is loop-controled with a double-axis piezo-actuator which follows the maximum intensity of the signal in the focal plane to compensate the pointing system's jitter. A single mode fiber ensures the optical path between the focal point and the photodiode.

12

"alOha" - A Dynamically Organized PLANET Data Plotting Environment

Jadzia DONATOWICZ

Technical University of Vienna - AUSTRIA

Microlensing planet searches depend critically on the ability to perform a real-time monitoring of an ongoing microlensing event. Firstly, one has to clearly identify the approaching high magnification microlensing events, as they have the highest efficiency to detect extrasolar planets. Secondly, one has to identify the very short-lived events that could be due to free floating planets. Thirdly, it is of key importance to monitor the ongoing anomalous events deviating from the single lens light curve to characterise the photometric perturbations.
The PLANET collaboration has used a suite of tools to perform these tasks over the past 15 years. Assessing the current technology framework especially the enormous spectrum of Open Source Software (OSS) available, we were able to design and implement a relatively simple but extremely powerful, dynamically organized plotting environment based on a completely different philosophy, best explained by its acronym. "alOha" is an " ALL OPEN SOURCE BASED, EARTH HUNTERS ASSISTANT" as it reflects both: the basic idea to set-up a system composed entirely of free and open-source software, suitable for building high-availability heavy-duty dynamic web site, capable of serving tens of thousands of requests simultaneously. This goal has been successfully realized by combining the following software components to set-up, develop and make available our dynamically organized, PLANET data plotting environment: LAMP server [Linux, Apache, MySQL, PHP], PHPlot, PDO interface [for MySql], bash, html].
a l O h a is currently in operation and is deployed to analyse and fast visualize the data of thousands ongoing microlensing events in the season 2015. As an easily scalable system it shapes a potential framework for the tools to be implemented in the era of the EUCLID and WFIRST space projects.

13

The impact of our limb-darkening assumptions on the retrieval of transit parameters

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In the era of high precision photometry, transit parameters derived from transit lightcurves have been able to provide parameters with uncertainties better than 1% on key ingredients used to constrain the internal composition of exoplanets. This in turn is allowing us to explore the diversity of exoplanet compositions among different masses an radii. However, transit parameters are obtained using several ingredients, one of the most important being limb-darkening. Using Kepler data I will show that our current understanding of limb-darkening is still incomplete and that, as a consequence transit parameters obtained by assuming perfect understanding of this effect are biased. In particular, I will show that if the quadratic law is used to parametrize this effect for Kepler lightcurves, both fixing and fitting the limb-darkening coefficients can lead to significant biases - up to $\sim 3\%$ and $\sim 1\%$ in the planetary radius, respectively - which are important for several confirmed and candidate exoplanets and has a direct impact on exoplanetary science. Strategies to avoid such biases in data from present and future missions involving high precision measurements of transit parameters will be described.

14

Searching for brown dwarfs in Chamaeleon I

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We present a survey for brown dwarfs in the Chamaeleon I star-forming region. Candidates were selected using proper motions and photometry measured from Spitzer, HST, VLT, and DECam. Through follow-up spectroscopy, we have confirmed several new brown dwarfs, including the least massive known members of the cluster ($\sim 5\,\mathrm{M}_{Jup}$). We use these results to obtain new constraints of the minimum mass of the IMF in Chamaeleon.

15

Giant planet formation via pebble accretion

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In the standard model of core accretion, the formation of giant planets occurs by two main processes: first, a massive core is formed by the accretion of solid material. Then, when this core exceeds a critical value (typically greater than 10 Earth masses) a gaseous runaway growth is triggered and the planet accretes big quantities of gas in a short period of time until the planet achieves its final mass. Thus, the formation of a massive core has to occur when the nebular gas is still available in the disk. This phenomenon imposes a strong time-scale constraint in giant planet formation due to the fact that the lifetimes of the observed protoplanetary disks are between $\sim 1\,\mathrm{Myr}$ and $\sim 10\,\mathrm{Myr}$. The formation of massive cores before $\sim 10\,\mathrm{Myr}$ by accretion of big planetesimals (with radii $> 10\,\mathrm{km}$) in the oligarchic growth regime is only possible in massive disks. However, planetesimal accretion rates significantly increase for small bodies, especially for pebbles which are strongly coupled with the gas. In this work, we study the formation of giant planets incorporating pebble accretion rates in our global model of planet formation.

16

Detecting the spin-orbit misalignment of the super-Earth 55 Cnc e

Guillaume HÉBRARD

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Time-resolved spectroscopy of transits of the super-Earth 55 Cnc e was obtained with HARPS-N. It allows an empirical correction for the "color effect" to be devised on the radial velocities. Using that correction, we were able to possibly detect the smallest Rossiter-McLaughlin anomaly amplitude of an exoplanet so far (~ 60 cm/s). The super-Earth 55 Cnc e would be also the smallest exoplanet with a Rossiter-McLaughlin anomaly detection. The derived sky-projected obliquity is lambda $= 72.4 + 12.7/-11.5$ degrees, indicating that the planet orbit is prograde, highly misaligned and nearly polar compared to the stellar equator. The entire 55 Cancri system may have been highly tilted by the presence of a stellar companion.

17

HARPS-N and SOPHIE joint follow-up of Kepler planetary candidates

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Radial velocity follow-up is mandatory to establish the nature of most of the transiting planet candidates detected with Kepler, then to characterize them and in particular to measure their mass and eccentricity. We started follow-up programs with the spectrograph HARPS-N that benefit from our SOPHIE observations on Kepler Objects of Interest. The goal of our HARPS-N programs is mainly to extend the SOPHIE results toward Kepler planetary candidates having lower masses, smaller radii, and/or fainter host stars. Our HARPS-N programs on Kepler planetary candidates and its results will be presented and discussed.

18

VIPER: toward a universal model for planetary climate

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We present VIPER, the Versatile Interactive PlanetSimulator for Extrasolar Research. This project, under development, aims at developing to a new level of modularity the Planet Simulator, an already flexible climate model developed at the University of Hamburg, which has already been applied to Earth, Mars, Titan, super-Earth and its dynamical core to hot Jupiters.

19

Transmission spectrum models of exoplanet atmospheres with haze: Effects of growth and settling of haze particles

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Since the first discovery of an exoplanet in 1995, detection of more than 1500 exoplanets has been reported. Recently, in addition to detection, multi-wavelength transit observations have been done to characterize detected exoplanets. From a decline in apparent stellar brightness due to a planetary transit, we can measure the planetary radius. Also, the observed wavelength-dependent radius (which is often called the transmission spectrum) provides the information of absorption and scattering of stellar light by molecules in the planetary atmosphere. Thus, the composition of the planetary atmosphere can be constrained by comparison between the observational and theoretical transmission spectra. The constraint on atmospheric composition is expected to give an important clue to the origin of the planet. Until today, transmission spectra of more than 20 exoplanets have been obtained. Some of the recent observations detected flat or featureless spectra, inferring the existence of particles such as hazes floating in the atmosphere. This means the existence of hazes would obscure the predicted spectral features of molecular absorption, making it difficult to prove its atmospheric composition. Also, the transmission spectra seem to be somewhat diverse. Some contain the Rayleigh-slope feature in the visible, some show molecular and atomic features in the near-IR.

These observational facts raise questions such as how common hazy atmospheres are beyond the solar system, how diverse transmission spectra of hazy atmospheres are, and how much information of atmospheric composition one can obtain from hazy atmospheres. There are a few theoretical studies of transmission spectra of exoplanet atmospheres that consider the effect of haze in the atmosphere (e.g., Howe & Burrows 2012; Morley et al. 2013). They treated the size, number density, and vertical distribution of haze particles as parameters. While they found parameter ranges in which the theoretical transmission spectra match the corresponding observations, they did not discuss if the viability of those haze properties is physically supported.

In this study, to derive realistic properties of hazes in the atmospheres of transiting exoplanets, we have developed a new theoretical model that considers the creation, collisional growth, and settling of haze particles. Also, with obtained properties of hazes, we have modeled transmission spectra of the atmospheres, using the numerical code that we developed previously. We have found that the haze particles tend to distribute in a wider region than previously thought and that haze particles of various sizes are formed in the atmosphere, which in general yield flat spectra. Simulating the transmission spectra for wide ranges of parameters concerning haze such as atmospheric composition, temperature, and UV irradiation from the host star, we constrain the parameter ranges that result in observed features in the transmission spectra. We also find the parameter ranges that show features of molecular absorptions in the spectra without being obscured by haze, making it possible to derive the information of the atmospheric composition from the observation of the transmission spectra.

20

Revisiting APOGEE's database with TODCOR: search for contact binaries and compact objects

Flavien KIEFER

University of Tel-Aviv - Israel

The last data release of the APOGEE (APO Galactic Evolution Experiment) survey (SDSS III) offers access to a large database of infrared spectra and radial velocity measurements of stars, among which a large proportion of binaries (around a couple thousand over more than 105 targets). The APOGEE instrument is a high resolution infrared spectrograph with a nominal resolution of 22,500 covering the 1.5 to 1.7 μm wavelength range. It is aimed to achieve a radial velocity precision of $\sim$100m/s. This is an ideal playground for the TODCOR two-dimensional multi-order correlation function method for the measurement of the radial velocities of binaries. The use of different stellar atmosphere spectral templates for each component of the binary makes it a very robust method to derive accurate radial velocities of the two components. Most importantly, this allows an exact derivation of the binary mass ratio, from which an estimation of the secondarys mass can be calculated. As a counterpart to TODCOR analysis for radial velocities, maximization of the 2D cross-correlation function with respect to stellar atmosphere templates, allows us to derive a fiducial estimation of both components temperature, surface gravity, metallicity and stellar rotations vsin(i).
In this poster, we present our selection highlights of APOGEE contact and/or large mass ratio binaries, with TODCOR radial velocities measurements and orbital solutions.

21

Toward a rigorous framework for radial velocities computations

Jacques LASKAR

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With the improving accuracy of radial velocities, it becomes important to improve also the determination of the Earth barycentric position and velocity that are used for the reduction of radial velocities measurements, and the recipes that were used in the present reduction software need to be updated in order to be sure that no error is introduced by an approximate estimate of the Earth's parameters. We have elaborated a new sets of routines for radial velocity reduction that is based on the latest version of the INPOP planetary ephemeris and on the SOFA routines for the Earth orientation. This set of routines will be made available for the astronomical community. In addition, we will discuss the new proposition that will be discussed at the next IAU General Assembly of a resolution that will propose some standard values for the Sun, Earth and Jupiter GM and radius values, to be adopted as units for extrasolar planet studies.

22

Unusual Light Curves with Short-Period Brightness Variations in the MOA Database

Man Cheung Alex LI

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A large volume of photometric data spanning eight years has been generated by the routine survey programme of the Microlensing Observations in Astrophysics (MOA) project towards the Galactic bulge. We aim to identify short-period eclipsing binaries in the MOA database which can be used for eclipse timing variation analysis. As the by-products of our search, we discovered at least three unusual light curves with short-period brightness variations. Two of them, both with periods ~ 2.2 days, might be associated with tidal excitation in non-eclipsing binary systems, based on our preliminary analysis. The other with period of ~ 0.5 days shows complicated brightness variations whose identity is totally unknown.

23

Close-in brown dwarfs and massive planets

Jorge LILLO-BOX

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The explanations for the paucity of substellar objects in close-in orbits around FGK stars (the brown dwarf desert) has been discussed for long time. The Kepler mission has provided unprecedented photometric precision, letting us detect and characterize several of these systems, also including massive planets in close-in orbits around their hosts.

In this poster, I present our recent detection of this type of objects by making use of the Kepler data and the tidal deformations induced by this close companions. We have partially filled the gap by deriving mass and radius for these substellar close-in companions, which are crucial for calibrating theoretical models.

24

Mass, Radius, and Orbital Architecture of hot Neptunes from Radial Velocities and Transit Variations

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We present the masses and radii of two hot Neptunes in the Kepler-25 system. The system is one of few examples for which both radial velocities and transit timing variations have been observed. We first analyze both data independently and test the consistency in the mass estimates. We then show how the joint analysis of the stellar radial velocities and transit timing variations can improve the constraints on the system parameters. We also analyze the variations in the transit durations to determine the mutual inclinations of the planetary orbits and discuss its relation with the spin axis of the host star.

25

Mass measurement through gravitational microlensing: non-inertial observers. Application to exoplanets and brown dwarfs

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The gravitational lensing (GL) of light rays emitted by a background source has lead to the discovery of dozens of extrasolar planetary systems during the last ten years. Moreover, it provides one of the very few methods to measure mass and abundance of free-floating planets and isolated brown dwarfs in the Galaxy. However, a limiting problem in undertaking such a measurement through GL is that a given observed light curve corresponds to different possible physical situations. In order to brake this degeneracy, one needs to take into account secondary effects which can modify the light curve. I will show how the accelerated motion of the observer generate a parallax effect which can lead to a mass measurement.

26

The C/O ratio's impact on hot and less hot Jupiter's spectra: A hint on the formation mode?

Paul MOLLIÈRE

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Due to location of water, CO_2 and CO icelines in the protoplanetary disk, the C/O ratio in the gas and in the planetesimals will vary as a function of radius (and time). Even in disks of solar C/O (~ 0.55), regions with C/O close to 1 in the gas phase might be possible. If organic compounds from the ISM survive the formation of the protoplanetary disk very high C/O ratios > 1 should be reachable in its inner regions. The C/O ratio of a planet might thus be indicative of its location of formation. Using our new 1-d radiative-convective equilibrium atmospheric code we present self-consistent atmospheric spectra of hot and temperate Jupiters, and show how a varying C/O ratio affects the spectral shape as a function of orbital separation to the star. We intend to couple these spectral calculations to planetary formation calculations which trace the planetary atomic abundances and C/O ratios. This will be done to further investigate and test whether the C/O ratio is a useful proxy for the planet's formation location.

27

Close-in Planets Around Evolved Stars: the Peculiar Case of Kepler-432b

Mauricio ORTIZ

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The number of Jupiter-like planets found to orbit evolved stars has constantly grown in recent years. These discoveries have found an apparent lack of close-in (< 0.5 AU) Jupiter-like planets orbiting giant/subgiant stars. If this scarcity of planets around evolved stars is not an observational effect, it could have important implications for planet formation/evolution models. We present the discovery of Kepler-432b, a weird case of a warm-Jupiter planet found to transit a giant star. This planet is among the most massive and dense transiting planets known so far and it is orbiting at only 0.3 AU from its host star with a period of ~ 52 days. The orbit is unusually eccentric ($e = 0.478 \pm 0.004$) for a planet around a giant star, and might be a tracer of its migration history. Kepler 432b occupies an almost desert region in the parameter space for planets around giant stars, which makes it a unique object for studying the evolution of planetary systems after the host star leaves the main-sequence. Current post-main-sequence evolution models predict that Kepler 432b will be swallowed by its host star in less than 200 million years. The planetary engulfment scenario might prove to be a key factor for explaining the apparent lack of close-in planets around evolved stars. Additionally, we found evidence of another planet/body in the system.

28

Investigating stellar activity by observations of planetary transits

Stefanie RAETZ

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Stellar activity can influence transit light curves in various ways. When a planet occults a spotty area on a stars surface, the flux increases and a characteristic feature in a light curve - a bump - is observed. Following a spot over several consecutive transits enables us to measure the stellar rotation period and the spin-orbit alignment. If the rotation period of a star is known it is possible to estimate the stellar age using gyrochronology. Host stars with large spots show a high magnetic activity and therefore appear to be young, hence such observations can provide constraints on the time-scale of planet formation and migration. Unocculted spots outside the transit path also affect a transit light curve. If spots are present the average temperature, hence the effective stellar radius is reduced. The observed transits are deeper than predicted by a spot-free model which leads to an overestimated planet-to-star radius ratio. We used high-precision ground-based transit observations combined with the unprecedented precision of continuous data provided by space telescopes i.e. CoRoT and Kepler to characterize the stellar activity and determine planetary and stellar parameters. I will present observations and results of one example for each of the two cases (occulted and unocculted spots): The light curve of CoRoT-18b reveal features that affect the transit shape and could be attributable to starspots. We used 3 ground-based observations and the 13 available CoRoT-transits to study the rotation of the star and the evolution of its photospheric active regions. For TrES-2 we analyzed seven years of ground based observations along with data of 18 observation quarters (Q0 - Q17) of the Kepler space telescope. The nearly continuous observations of Kepler yielded a slight increase of the planet-to-star radius ratio, which could be an indication of an increasing stellar activity. I will show that the change in spot coverage that causes the increasing transit depth seems to be plausible compared to the solar cycle.

29

How reliable is an extrasolar planet detection claim when stellar noise is unknown? An efficient approach with statistical control of the detection significance

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Future space-based instruments as PLATO for transits or ESPRESSO for radial velocities will obtain very long time series of data with very low detector noise. In such cases, extrasolar planet detection will be essentially limited by stellar noise. This noise is a stochastic process, with poorly known and star-dependent statistics. Its power is expected to dominate that of the faintest targeted extrasolar signatures. This new adversarial random process challenges the relevance of traditional parametric models used in current detection approaches - in particular, their reliability in terms of statistical significance. In the same time, the promising developments of 3D hydrodynamical simulation techniques open new perspectives on the possibility of accurately modeling stellar noise. We propose in this contribution to exploit such simulations in the detection process. We show that if the simulation process is accurate enough, the proposed method is powerful for virtually all types of stellar noises and weak extrasolar signatures, while precisely controlling the reliability in the detection claims.

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Atmospheric escape by magnetically driven wind from gaseous planets and atmospheric structures

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We calculate the mass loss driven by magnetohydrodynamic (MHD) waves from hot Jupiters by using MHD simulations in one-dimensional flux tubes. If a gaseous planet has a magnetic field, MHD waves are excited by turbulence at the surface, dissipate in the upper atmosphere, and drive gas outflows. Our calculation shows that mass-loss rates are comparable to the observed mass-loss rates of hot Jupiters; therefore, it is suggested that gas flow driven by MHD wave energy can play an important role in the mass loss from gaseous planets. The mass-loss rate varies dramatically with radius and mass of a planet: a gaseous planet with a small mass but an inflated radius produces very large mass-loss rate. We also derive an analytical expression for the dependence of mass-loss rate on planet radius and mass that is in good agreement with the numerical calculation. The mass-loss rate also depends on the amplitude of the velocity dispersion at the surface of a planet, and the surface temperature. Thus, we expect to infer the condition of the surface and the internal structure of a gaseous planet from future observations of mass-loss rate from various exoplanets. In addition, we are calculating the atmospheric escape and the structure of the atmosphere with resistive MHD. Because of low ionization degree and high magnetic resistivity, MHD waves diffuse in the atmosphere. I will also discuss current results of our calculation.

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Water condensation during formation: the impact on the critical core mass

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During the formation of a planet, once the core reaches a lunar mass, it can start to bind some gas from the protoplanetary disk. The planetesimals that are accreted from this stage on, undergo thermal ablation and physical disruption when crossing the atmosphere. Thus, the primordial H-He atmosphere gets enriched in volatiles and silicates from the planetesimals. This change of composition affects the thermal structure of the atmosphere. In particular, if the planet is located in a region where the temperature and pressure are suited for water condensation to take place, the release of latent heat modifies drastically the adiabatic temperature gradient. We will discuss how this effect reduces the critical core mass and the implications this has for the type of planets that can be formed.

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The SOPHIE search for northern extrasolar planets: Exploring the planet-brown dwarf boundary

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Radial velocity planet search surveys of nearby solar-type stars have shown a strong deficit of brown dwarf companions within $\sim 5\,\mathrm{AU}$. There is presently no comprehensive explanation of this lack of brown dwarf companions, therefore, increasing the statistics of such objects is crucial to understand their formation and evolution. We present the results from a high-precision radial-velocity survey aimed at characterising companions to solar-type stars with minimum masses distributed across the brown dwarf regime. We report the detection of 15 new massive companions to solar type stars based on precise radial velocities obtained with the SOPHIE spectrograph at Observatoire de Haute Provence. These companions have minimum masses well distributed across the brown dwarf mass regime 10 - 80 M_{Jup} and therefore are an important contribution of the known population of massive companions around solar-type stars.

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Follow-up observation of microlensing at Kohyama Astronomical Observatory

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Galactic microlensing events provide us a unique opportunity to detect exoplanets. Basically, different from other major detection methods, i.e., radial velocity or transit, a signal due to exoplanets does not repeat. Thus, cadent observations are essential for this method, and collaboration of wide area monitoring (e.g., MOA, OGLE) and follow-up observations are important. From 2011 season, we have started follow-up observation of microlensing at Kohyama Astronomical Observatory in Kyoto Sangyo University. Our observatory is not dedicated for the follow-up observation, but we had successfully detect flux variation due to microlensing in many events. With this presentation, we will report current status, results, and possible anomaly detected by our observatory.

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New approach to identify planetary or brown dwarf companion in a circumstellar disk based on spectral energy distribution profile of the system

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Giant planets and brown dwarfs, that form via protostellar disk fragmentation, start their formation process at first 100 thousand years as a consequence of disk gravitational instability. Rocky planets form later, through the coagulation of planetesimals. Common feature in both formation scenarios is that once companion reaches stable orbit (especially if orbit is circular), it starts to clear a gap in the disk along its orbital movement. It is almost impossible to detect the planet around the star by studying the spectral energy distribution (SED), due to the big difference of their luminosities. But it is possible to suspect a companion based on the parameters of the gap cleaned by it, that could be derived based on the analysis of SED profile. We investigate a possibility to suspect substellar or planetary companion in circumstellar disk via SED profile analysis and analyze companions physical parameters that can be derived with this method. We will present the synthetic spectral energy distributions (SEDs) of the protoplanetary and debris disks with embedded companions that is located within all possible positions along the disk radius. Companion masses vary from 10 Earth masses to 40 Jupiter masses.

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SED simulation results of a possible ring around the young brown dwarf G196-3B

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The origin of the very red colors of intermediate-age ($\sim$ 50 - 500 Myr) L-type dwarfs remains unknown. It has been suggested that low-gravity atmospheres containing large amounts of dust may account for the observed reddish nature. We explore the feasibility of the presence of primordial and debris disks by fitting the spectral energy distribution of G196-3B, one L3 brown dwarf with clear near- and mid-infrared color excesses, and estimated age and mass in the intervals 20 - 300 Myr and 0.012 - 0.025 $M_{\odot}$. The best-fit found responds to the scenario of a warm ($\sim$ 1270 K), very narrow debris ring (0.35 - 0.37 $R_{\odot}$) with a mass 4×10^{-11} $M_{\oplus}$ and located very close to the central brown dwarf, somehow resembling the rings of Neptune and Jupiter. We also determine that in addition to the ring, it could be a massive outer disk or a low-mass outer ring, depending on the surface density radial profile that we can't determine uniquely with available observations. The inclination angle of the disk also cannot be properly constrained with current data.

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Identification of the nature of metal-poor low-mass subdwarfs

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L type subdwarfs could be massive planets expelled from their proto-planetary disk or brown dwarfs. Known galactic halo low mass objects are rare compared to their counterparts of the Galactic thin and thick disc. Our knowledge of them is therefore limited. I will report our latest discovery of new halo substellar subdwarfs. Our targets are selected from UKIDSS and SDSS, and followed up with large telescopes (VLT, GTC and Magellan). Our new discovery has largely increased the sample of known halo low mass objects. I compare our new sample with models to establish by a composition determination the nature of these low mass objects. I discuss their spectral signature and how future facilities will help us to understand their populations.

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