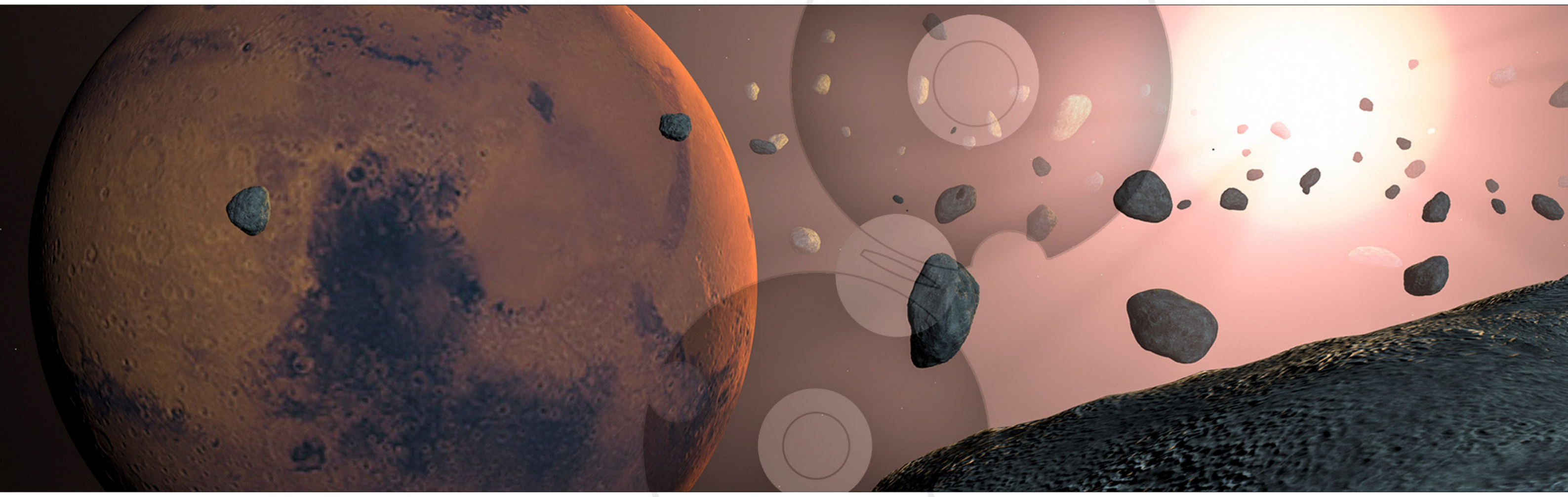
# Characterizing Planetary Systems Across the HR Diagram - *Poster Abstracts*



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Characterizing Planetary Systems Across the HR Diagram
at the Institute of Astronomy, University of Cambridge, UK

Aimée Hall • Institute of Astronomy, Cambridge, UK

*Neptunes in the Noise: Improved Precision in Exoplanet Transit Detection*

1

SuperWASP is an established, highly successful ground-based survey that has already discovered over 80 exoplanets around bright stars. It is only with wide-field surveys such as this that we can find planets around the brightest stars, which are best suited for advancing our knowledge of exoplanetary atmospheres. However, complex instrumental systematics have so far limited SuperWASP to primarily finding hot Jupiters around stars fainter than 10th magnitude. By quantifying and accounting for these systematics up front, rather than in the post-processing stage, the photometric noise can be significantly reduced.

In this paper, we present our methods and discuss preliminary results from our re-analysis. We show that the improved processing will enable us to find smaller planets around even brighter stars than was previously possible in the SuperWASP data. Such planets could prove invaluable to the community as they would potentially become ideal targets for the studies of exoplanet atmospheres.

Alan Jackson • Arizona State University, USA

*Stop Hitting Yourself: Did Most Terrestrial Impactors Originate from the Terrestrial Planets?*

2

Although the asteroid belt is the main source of impactors in the inner solar system today, it contains only 0.0006 Earth mass, or 0.05 Lunar mass. While the asteroid belt would have been much more massive when it formed, it is unlikely to have had greater than 0.5 Lunar mass since the formation of Jupiter and the dissipation of the solar nebula. By comparison, giant impacts onto the terrestrial planets typically release debris equal to several per cent of the planet's mass. The Moon-forming impact on Earth and the dichotomy forming impact on Mars, to consider but two of these major events, each released $>1$ Lunar mass in debris, over 50 times the present day asteroid belt. This escaping impact debris is less long lived than the main asteroid belt, as it is injected on unstable, planet-crossing orbits, but this same factor also increases the impact probability with the terrestrial planets and asteroids. We show that as a result terrestrial ejecta played a major role in the impact history of the early inner solar system, and we expect the same is also likely to be true in other planetary systems.

Alex Dunhill • PUC Chile

*The Curiously Circular Orbit of Kepler-16b*

3

The discovery of a number of circumbinary planets lends a new tool to astrophysicists seeking to understand how and where planet formation takes place. Of the increasingly numerous circumbinary systems, Kepler-16 is arguably the most dynamically interesting: it consists of a planet on an almost perfectly circular orbit ($e = 0.0069$) around a moderately eccentric binary ($e = 0.16$). I will present high-resolution 3D smoothed-particle hydrodynamics simulations of a Kepler-16 analogue embedded in a circumbinary disc, and show that the planet's eccentricity is damped by its interaction with the protoplanetary disc. Using this, one can place a lower limit on the gas surface density in the real disc through which Kepler-16b migrated. This suggests that Kepler-16b, and other circumbinary planets, formed and migrated in relatively massive discs. I argue that the has strong implications for the route that planet formation takes in the circumbinary environment, as secular evolution of circumbinary discs requires that these planets formed early on in the lifetime of the disc and migrated inwards before the disc lost a significant amount of its original mass.

Amaury Thiabaud • CSH - University of Bern, Switzerland

*Planetary Composition in Planet Formation Models*

4

Computing the chemical composition of planet is a growing need for planetary formation models. Previous works have been investigating the chemical composition of planet, combining dynamical process of planetary formation and chemistry. However, either these studies have only focused on the volatile content of the planets (CO,H2O,CO2,CH4...) either the composition of the planets have been determined in a non self-consistent manner. We present here results of calculations of chemical compositions of planets with the combination of the planetary formation model of Alibert et al. (2013, and references therein) and the condensation sequence theory. We derive the most important elements for which the knowledge of the stellar abundance is needed to compute the composition of the planet that can be formed. To do so, we vary the initial stellar composition in the chemical model, and investigate possible correlations between different ratios in stars and planets.

Amaury Triaud • Massachusetts Institute of Technology, USA

*Colour Magnitude Diagrams of Transiting Exoplanets*

5

Colour-Magnitude diagrams form a traditional way of representing luminous objects in the Universe and compare them to each others. We can measure the flux emitted by a planet's dayside when it undergoes an occultation. Combining this flux with a distance measurement, the absolute magnitude of that planet can be estimated. Colour-magnitude diagrams are composed in the near and mid infra-red for 44 transiting extrasolar planets. When possible, planets are plotted alongside very low-mass stars and field brown dwarfs, who often share similar sizes and equilibrium temperatures. They offer a natural, empirical, comparison sample. We also include directly imaged exoplanets and the expected loci of pure blackbodies.  Irradiated planets do not match blackbodies; their emission spectra are not featureless.  For a given luminosity, hot Jupiters' daysides show a larger variety in colour than brown dwarfs do and display an increasing diversity in colour with decreasing intrinsic luminosity. The presence of an extra absorbent within the 4.5 micron band would reconcile most hot Jupiters with ultra-cool dwarfs' atmospheres. Measuring the emission of gas giants cooler than 1000 K would disentangle whether planets' atmospheres behave more similarly to brown dwarfs' atmospheres than to blackbodies, whether they are akin to the young directly imaged planets, or if hot Jupiters form their own sequence.

Andrew Shannon • Institute of Astronomy, Cambridge, UK

*Rocky Bodies in the Oort Cloud*

6

Oort cloud comets are icy bodies with semimajor axes of thousands to tens of thousands of AU.  Formation at such large distances from the Sun is believed to be impossible, and Oort cloud comets are generally believed to have formed in the outer solar system.  They were then injected into the Oort cloud via scattering by the giant planets, and subsequently had their pericentres raised by the galactic tide and perturbations from passing stars.  This dynamical path should not be exclusive to small outer solar system bodies, inner solar system should also sometimes follow a similar path.  Consequently, some fraction of the Oort cloud should consist of rocky bodies without significant ice.  We explore this pathway for the solar system with N-body simulations augmented with the galactic tide and stellar flybys, and estimate the fraction of Oort cloud comets that should have originated in the inner solar system, and hence contain no ice.  The occurrence rate of rocky bodies among Oort cloud comets can provide strong constraints on models of the solar system's history and planet formation.

Andrzej Niedzielski • Nicolaus Copernicus University, Poland

*Low-Mass Companions To Evolved Stars*

7

Searches for planets around stars beyond MS are important in building a complete picture of planet formation and evolution.  First of all the allow to reach to object with masses significantly larger than solar (Sato et al. 2012).  Secondly these planetary systems are old and suitable for long-term dynamical stability considerations (Mustil et al. 2014). They are also subject to changes induced by stellar evolution (Villaver & Livio 2007, 2009) and therefore important for studies of stars - planet interactions (e.g. Adamów et al. 2012) and tests of stellar evolution as they may form for example asymmetric planetary nebulae (Harpaz & Soker 1994; Soker 2006). They also carry information on the initial population of planetary systems around White Dwarfs  (Farihi et al. 2010).

Over 1000 stars are monitored with the Hobby-Eberly Telescope for RV variations since 2004. The sample is composed of evolved low- and intermediate- mass stars: 350 Red Clump Giants, 450 Giants and Subgiants and 250 Evolved Dwarfs. 13 stars with 15 planetary-mass companions have already been already discovered within the project (Niedzielski et al. 2007, 2009a, b; Gettel et al. 2012a, b; Nowak et al. 2013). Another 300 low-mass companions candidates were identified in the sample and are now monitored with several telescopes.
I will present in detail the sample, current status and a few new planets from our project which primary goal is to improve our understanding of the evolution of planetary systems around aging stars (Niedzielski et al. 2007; Niedzielski & Wolszczan 2008).

Antonio Hales • ALMA/NRAO, Chile

*Sub-mm Studies of Herbig Ae/Be Stars*

8

We present new sub-millimeter data of Herbig Ae/Be stars, taken with single dish telescopes in Chile, in order to search for continuum and gas emission around these system. We detect 12CO emission around at least  two systems, as well as the 870 micron continuum. The new sub-mm data is input into the radiative transfer code MCFOST (Pinte et al. 2006) to produce disk models that fit the entire SEDs. The models reproduce well the observed CO line profiles, constraining the properties of the circumstellar disks.

Carlos Bacigalupo • Macquarie University, Australia

*Open Cluster Spectroscopy with the HERMES Multi-Object Spectrograph*

**9**

HERMES, the new spectrograph at the Anglo Australian Telescope, is designed to observe ~400 simultaneous targets at R~28000. Spectra collected from open clusters allow asteroseimology analysis of giant stars and the search for hot jupiters around main sequence stars. This provides the advantage of sampling several members of the same cluster, allowing us to determine stellar properties by association and derive results with higher precision than those obtainable from individual stars. Using a physically motivated wavelength scale model, we tested this proof of concept in two open clusters, M67 and NGC2477. The custom built addition to the standard analysis pipeline allows us to increase the radial velocity precision measurements beyond the values yielded by the standard data reduction process. Although our pilot observations yielded only 2 clear nights, simulations of radial velocity fluctuations in giant stars show that 4 nights are required to obtain a 2.5% precision measurement of the frequency of the largest amplitude oscillation in ~1.4 solar mass stars. This can be obtained by extracting information from a minimum of 30 stars. Using calibrations from Kepler and calculating the stellar temperatures from individual stellar spectra, we can determine stellar masses in the cluster with an 8% precision, or the differential mass between the first ascent giant branch and the red clump to at least 4% precision. This technique can potentially allow us to identify red giants from horizontal branch stars.

Carolina Bergfors • University College London, UK

*Completing the Census of IR Bright Disks at Nearby Polluted White Dwarfs*

**10**

Dust disks created by tidal disruption of minor planets have been observed around metal polluted white dwarfs using a variety of techniques, providing important clues to the fate of terrestrial planetary systems at 2-3 Msol stars.
We present results from Spitzer IRAC observations of 15 white dwarfs; a few of which are highly polluted, but most of which show modest metal abundances. We find two, and possibly three, new stars with disks, all of which show rather subtle infrared excesses. One of these is the coolest star known to exhibit an excess at 3 microns, and the first DZ type star with a bright disk. All together our data corroborate a picture where 1) disks at metal-enriched white dwarfs are commonplace and most escape detection in the infrared, 2) the disks are long lived, having lifetimes on the order of 1e6 yr, and 3) the frequency of bright, IR detectable disks decreases with age, on a timescale of roughly 500 Myr, suggesting large planetesimal disruptions decline on this same timescale.

Cezary Migaszewski • Szczecin University, Poland

*On the orbital architecture of the HR 8799 planetary system*

**11**

So far, a young A5V star HR 8799 hosts the only multi-planet system detected using the direct infrared imaging. It consists of four planets of ~10 Jupiter masses in wide orbits between ~25 and ~70 au. A determination of the orbital parameters is a challenging task because the observational windows of ~2 to ~13 years are narrow when compared to the orbital periods between ~50 and ~500 years, and the system is dynamically packed. Many different orbital configurations are possible. A requirement of stable system for the star lifetime makes the problem even more difficult. In a recent paper (Gozdziewski & Migaszewski, 2013), we have proposed a new self-consistent algorithm to constrain the orbital parameters through the planetary migration. Our method relies on the assumption that the planets were formed in wide orbits and then migrated inwards to their current positions. We found basically unique solution in which the planets are involved in a double Laplace mean motion resonance 1:2:4:8. This is the first known rigorously stable configuration of this type in the literature. It is also the first orbital model of the HR 8799 system, which is fully consistent with independent mass estimates from cooling models, debris disk analysis and the star orientation in space. Moreover, the new fitting method makes it possible to predict stable configurations with the fifth, innermost yet undetected planet with ~6 Jupiter masses involved in a triple Laplace resonance 1:2:4:8:16 or in the 1:3:6:12:24 mean motion resonance.

Chao-Chin Yang • Lund University, Sweden

*On the Feeding Zone of Planetesimal Formation by Streaming Instability*

12

In current theory of planet formation, streaming instability is one of the most promising mechanisms to overcome the meter-barrier in the course of core accretion. Almost all previous studies, however, were focused on a local region of protoplanetary disks with a limited size such that only one radial filamentary concentration of solids was observed. To address this, we conduct the largest-scale simulations of this kind to date, up to 1.6 gas scale heights both horizontally and vertically, with which the vertical stratification of the gas becomes prominent. We demonstrate that large vertical and horizontal extent of the simulation box is indeed required to achieve numerically convergent results. More importantly, we find multiple filamentary concentrations of solids with an average separation of about 0.5 local gas scale heights, which measures the characteristic size of the formation zone of planetesimals by the streaming instability. This result is used to compare with the populations of the asteroid and Kuiper belts in the Solar system.

Christina Hedges • Institute of Astronomy, Cambridge, UK

*Importance of Accurate Molecular Spectroscopy for Characterizing Exoplanetary Atmospheres*

13

Recent advances in exoplanetary spectroscopy over the past few years have opened up detailed characterization of exoplanetary atmospheres. Using spectroscopic observations it is possible to determine elemental and molecular abundances within the atmospheres of exoplanets with high statistical significance. These data can be used to further investigate various atmospheric processes, such as non-equilibrium chemistry, temperature inversions, atmospheric dynamics, and the presence of clouds in these planets. Critical to the interpretation of spectra, however, is the reliability of the fundamental input parameters to the models such as the atomic and molecular absorption cross-sections derived from the corresponding line-lists. With transition line-list data being recently updated for many of the relevant molecules, at much higher temperatures than was previously available, it is now possible to scrutinise the transition features of these molecules and the application of high temperature line-lists to atmospheric studies. Molecular transition features vary under different temperature and pressure regimes and this variance affects the detection of atmospheric lines in given bandpasses. In this work we demonstrate the importance of accurate line-lists and broadening parameters for calculating reliable molecular cross sections and discuss their implications for abundance determination in exoplanetary atmospheres. We present an investigation into the relevant molecules for atmospheric studies and how their absorption features correlate with the bandpasses of instruments involved in exoplanet spectroscopy. We identify optimal bandpasses on current and future instruments available for atmospheric characterisation of exoplanets and discuss the impact on future work.

Cristobal Petrovich • Princeton University, USA

*Kozai-Lidov Migration in Stellar Binaries*

14

We study the orbital evolution of giant planets migrating by the combination of the Kozai-Lidov (KL) mechanism in stellar binaries and tidal friction from the host star. By comparing the observed semi-major distribution of hot Jupiters with our Monte Carlo simulations, we conclude KL migration can explain the observations only if: (1) tidal dissipation in the planets is at least ~150 times more efficient than that inferred from the Jupiter-Io interaction, (2) Jupiter-like planets are tidally disrupted at separations of ~0.015 AU. Finally, we place constraints on the efficiency of this mechanism to produce: hot Jupiters, collisions with the star, and tidal disruptions, and discuss how these depend on the properties of the binary companion.

Dan Maoz • Tel-Aviv University, Israel

*Finding and Characterizing Habitable-Zone Planets Around White Dwarfs*

15

The growing evidence for rocky and water-rich debris around white dwarfs (WDs) strongly suggests that terrestrial planets may be common near their tidal disruption radii, which roughly coincide with their continuously habitable zones. Due to the small sizes of WDs, a planet transiting a WD will provide a very favourable contrast for characterising the planet atmosphere's transmission spectrum. JWST will be able to detect bio-markers in habitable-zone WD planets with several hours of total in-transit integration. This is probably the only circumstance with the potential for discovery of extra-solar bio-markers in the near term. I will describe ongoing efforts to discover the population of nearby, ~3-Gyr-old WDs, and to find those that are orbited by transiting habitable-zone planets, in time for their study by JWST, when launched in 2018.

Daniel Bayliss • ANU, Australia

*The HATSouth Discovery of a Hot Jupiter Transiting an m-Dwarf*

16

Though m-dwarfs constitute the majority of stars in our Galaxy, will still understand little about the planets that orbit these low mass stars. To begin to understand these systems requires the discovery of exoplanets that transit m-dwarfs, yet this has proved difficult due to the extreme lack of m-dwarfs in magnitude limited surveys. The HATSouth global network of telescopes, with larger aperture telescopes than previous ground-based surveys, is probing deep enough to provide an opportunity to discover transiting exoplanets around m-dwarfs. Here we report on the discovery of a transiting hot Jupiter around an m-dwarf and discuss the consequences of the discovery for this class of exoplanet.

Danielle Piskorz • California Institute of Technology, USA

*Friends of Hot Jupiters : Searching for Low-Mass Stellar Companions via Spectroscopic Model Comparison*

17

Surveys of the solar neighborhood indicate that approximately half of all Sun-like stars are found in binaries or higher order multiples, but the potential effects of a stellar companion on the formation and evolution of planetary systems is unclear. Although most exoplanet surveys have focused on apparently single stars, it is possible that some of the known FGK planet-hosting stars also have unresolved stellar companions. If they exist, such companions are likely low mass M stars, which are easily overlooked in seeing-limited imaging and visible-light spectroscopy. In this study we search for stellar companions to systems with known transiting hot Jupiters. A yet-unobserved stellar companion could be dynamically responsible for a hot Jupiters misaligned orbit and shot period. Using NIRSPEC at Keck Observatory, we have acquired high-resolution spectra of fifty hot Jupiter hosts near 2.3 microns. We search for the unique molecular fingerprint of a cool stellar companion blended with the light from the hotter primary and perform a model comparison to determine the likelihood of a low-mass stellar companion contributing to the observed spectrum. This method has yielded ranked list of candidate stellar companions in these systems. Our follow-up efforts to directly resolve these companions involves high contrast adaptive optics imaging. In combination with the radial velocity (see abstract by Bryan et al.) and adaptive optics (see abstract by Ngo et al.) portions of the Friends of Hot Jupiters survey, these data allow us to place strong constraints on the frequency of stellar companions in hot Jupiter systems.

David Swoboda • University of Bern, Switzerland

*Analysis of Multiplanetary System Population Synthesis*

18

Planet formation models have been developed during the last years in order to try to reproduce and predict observations of the solar system and extrasolar planets. Using a modular planetary system formation model combining an extended core-accretion model including migration and disc evolution with an N-Body part for the dynamical interactions we perform population synthesis calculations in order to investigate the effects of different parameters for both the planetesimal and the gas disc and the competition and gravitational interactions of more than one planet forming in the same protoplanetary disc. We show the modification of masses, semi-major axes, period-ratios and general layout and stability of the resulting planetary systems varying the viscosity, irradiation by the star and the location and size of a dead zone.

David Wilson • University of Warwick, UK

*A Variable Gaseous Disk Around the Metal-Polluted White Dwarf SDSS J1617+1620*

19

Several dozen white dwarfs have close-in dusty discs that are visible as an infrared excess over the photospheric emission of the white dwarf. In a small number of systems an additional gaseous component is detected by double-peaked line emission emission in the CaII 8600A triplet. The dynamical analysis of the line profile shape shows that the radial extent of the gas overlaps with that of the dust, both residing within the tidal disruption radius of the white dwarf. The origin of these gaseous discs is not well understood: on the one hand, sublimation of the dust by irradiation from the white dwarf is insufficient to heat the gas to the temperatures implied by the CaII emission, and on the other hand most white dwarfs with dusty discs do not show evidence for a gaseous component. Here we present time-series spectroscopy of the DA white dwarf SDSS J1617+1620 obtained from 2006 to 2013, which shows the transient appearance of strong, double-peaked CaII emission lines in 2008, and only very weak lines before and after that epoch. Possible explanations for this unprecedented variability include the impact of a small planetesimal onto an existing circumstellar dust disc, or the periodic passage of a debris tail in an eccentric orbit.

Dimitri Veras • University of Warwick, UK
*Linking the Birth and Death of Planets Through the Process of Anisotropic Stellar Mass Loss*

20

The birth and death of planets may be affected by mass outflows from their parent stars during the T-Tauri or post-main-sequence phases of stellar evolution. These outflows are often modeled to be isotropic, but this assumption is not realistic for fast rotators nor bipolar jets. Here we present relations for the time evolution of a single planet, brown dwarf, comet or asteroid perturbed by anisotropic mass loss in terms of a complete set of planetary orbital elements, the ejecta velocity, and the parent star's co-latitude and longitude. We consider (1) rapidly rotating giant stars, and (2) arbitrarily-directed jet outflows. We conclude that the isotropic mass-loss assumption can safely be used to model planetary motion during giant branch phases of stellar evolution within distances of hundreds of au. In fact, latitudinal mass loss variations anisotropically affect planetary motion only if the mass loss is asymmetric about the stellar equator. Also, we demonstrate how constant-velocity, asymmetric bipolar outflows in young systems incite orbital inclination changes. Consequently, this phenomenon readily tilts exoplanetary orbits external to a nascent disc on the order of degrees.

Eleanor Bacchus• Institute of Astronomy, Cambridge, UK
*Detection and Characterisation of Faint Companions with Project 1640*

21

Project 1640 is a direct imaging survey with the ability to simultaneously gain images and low resolution spectra of faint companions around nearby stars. The spectra span the H and J bands in the near infra-red and enable the detection of broad molecular absorption lines, allowing basic atmospheric modeling to be done and helping to characterise imaged companions. In particular we will be able to investigate the boundary between exoplanets and brown dwarfs and shed light on companions whose masses fall on the borderline between these two regimes. We are currently conducting a survey of near A-F type stars with the aim of detecting young, Jupiter mass planets at separations of around 1"-2" from their host stars. We have also undertaken several observations of known companions, in order to provide spectra and further astrometric data to help refine photometric and orbital parameters for these objects and to start investigating their atmospheric properties.

Elodie Thilliez• Swinburne University of Technology, Australia
*Numerical Predictions for Planets in the Debris Discs of HD202628 and HD207129*

22

Resolved debris disc images can exhibit a range of radial and azimuthal structures, including gaps, rings and warps, which can result from planetary companions shaping the disc by their gravitational influence. Currently there are no tools available to determine the complete architecture of the companion systems from disc observations. Recent work by Rodigas et al. (2014) present a framework by which one can estimate the maximum mass and minimum semi major axis of a planet from the debris disc's width in scattered light. In this work, we use the predictions of Rodigas et al. applied to HD 202628 and HD 207129 and numerically search for a better estimate of the companions' parameters. We perform simulations using a modified N-body code which include radiation forces for a broad range of input parameters and compare synthetics images from our simulations to the scattered light observations of Krist et al. (2010, 2012).

Farisa Morales • JPL, USA
*Herschel-Resolved Two-Belt Spitzer Debris Disks*

23

We use Herschel PACS imaging for a unique set of stars that host on going activity in the terrestrial planet zones and the presence of an outer/colder dust component, to continue the exploration, begun with Spitzer Space Telescope, of their disk structure and composition. The 19 solar— and A—type stars presented here have combined Spitzer IRS+MIPS (5 to 70 µm) and Herschel PACS (70 or 100 and 160 µm) SEDs suggesting a two—ring disk architecture, mirroring that of the asteroidal-Kuiper belt geometry of our Solar System. In addition, Herschel provides the sensitivity and angular resolution required to successfully resolve them at 70, 100, and/or 160 µm. Spatially resolved systems help breach the degeneracy in SED modeling between the grain properties and the dust's radial location. The goal is to analyze the Herschel-resolved disks within our Spitzer sample in order to compare the architecture of other planetary systems against our own, and to improve understanding of how planetary systems form and evolve.

Farzana Meru• ETH Zürich, Switzerland

*Planetary Systems in the Making: Interactions Between Multiple Planets and their Parent Disc*

24

We propose a mechanism by which dust rings in protoplanetary discs can form and be long-lasting, which combines the idea of trapping dust in a pressure maximum ring between two planets followed by the decoupling of these particles due to a decrease in the ring's surface density over time. We perform 2D gas hydrodynamical simulations to investigate the disc structure in the presence of two giant planets placed sufficiently far apart such that they do not open a common gap. We find that with two 1 MJup planets that open deep gaps and two 0.2 MJup planets that open partial gaps, a ring of material forms in between the two planets with the surface mass density being higher than either side of the ring. The ring is a region of pressure maximum where we expect larger grains to collect as a gap is easier to form in the large dust than the gas or smaller grains. Over time the gas surface density in the ring decreases which might cause some large particles that were marginally coupled to the gas (but trapped in the ring due to the pressure maximum) to begin to decouple. Consequently, as the surface density of the gas ring decreases over time the dust ring (larger sized particles) are expected to remain in the ring structure longer than the gas ring. For a MMSN model, we expect that millimetre and centimetre-sized grains in the outer O(10) au in a disc would be the ones that are most likely to be trapped and decoupled by this mechanism.

Florian Rodler• MPIA/ Harvard-Smithsonian CfA, USA

*Feasibility Studies for the Detection of Oxygen in the Atmospheres of Exo-Earths with Future Instrumentation*

25

We present the results of simulations on the detectability of O2 in the atmosphere of Earth twins around nearby low mass stars using high resolution transmission spectroscopy. We explore such detectability with each of the three upcoming Extremely Large Telescopes (ELTs), i.e. GMT, TMT and E-ELT, and high resolution spectrographs, assuming such instruments will be available in all ELTs. With these simulations we extend previous studies by taking into account atmospheric refraction in the transmission spectrum of the exo-Earth and observational white and red noise contributions. We find that, unless unpredicted instrumental limitations arise, the implementation of pre-slit optics such as image slicers appear to be key to significantly improve the yield of this particular science case.

Giovanni Rosotti• MPE, Germany

*X-ray Photoevaporation and Planet Formation Interplay in the Dispersal of Protoplanetary Discs*

26

Planet formation is a race between the processes aggregating the material in the proto-planetary disc and the ones removing it, dispersing the disc. The so-called transition discs show evidence for an inner hole and are interpreted as discs caught in the final act of dispersal. Photo-evaporation and planet formation itself have been proposed as mechanisms responsible for their creation. However, both scenarios have problems in explaining the measured hole sizes and mass accretion rates. I have studied the combined effect of the two processes, finding that it can significantly alter the picture. In particular, I find that the formation of a giant planet can trigger the creation of a short-lived transitional disc and its final dispersal by photo-evaporation. I will show results from a suite of 2d simulations of protoplanetary discs undergoing X-ray photoevaporation with an embedded giant planet. I have expanded the parameter space investigated by the previous simulations with the goal of making comparisons with observations (e.g., more massive discs). In addition, while before the simulations were run only up to hole opening, the updated model includes thermal sweeping, needed for studying the complete dispersal of the disc. The suite of simulations allows me to construct statistical predictions about the transitional disc population, that can be compared against the upcoming ALMA observations.

Henry Ngo • California Institute of Technology, USA

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*Friends of Hot Jupiters: Finding Distant Stellar Companions with NIRC2 AO*

Due to their large masses, hot Jupiters must have formed beyond their stars' ice line and then migrated inwards to their present locations. So far, the migration mechanism remains a mystery. A stellar companion could drive a hot Jupiter's migration and also explain the observed spin-orbit misalignments of some hot Jupiter systems. However, a companion may also hinder planet formation by dynamically exciting and/or truncating the protoplanetary disk.

We present our adaptive optics (AO) imaging survey which measures the fraction of hot Jupiters found in multiple star systems. Over the past two years, we completed a survey of 51 targets ("Friends of Hot Jupiters") and found 17 stellar companions around 15 stars. Here, we present these detections along with characterizations of their masses and projected physical separations. The multiple year baseline allows us to check for common proper motion to confirm that these companions are gravitationally bound. In addition, we will present preliminary results of an expanded survey containing an additional 146 targets that host planets spanning a wider range of masses and orbital periods. This AO survey is one part in a larger campaign with different companion detection modes such as long term radial velocity monitoring (Bryan et al., this meeting) and high resolution infrared spectroscopy (Piskorz et al., this meeting). In combination with these other modes, we are sensitive to a large range of companion separations and masses. Thus, we can test whether distant companions are responsible for the inward migration and/or the spin-orbit misalignment of hot Jupiters.

Illeana Gomez Leal• Max-Planck-Institute für Astronomie, Germany

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*Thermal Light Curves of Earth-like Planets: Orbital and Climatic Conditions*

The thermal light curves are a key to characterize the physical and chemical properties of its atmosphere as well as their evolution. The emission is modulated by the orbital parameters of the planet, the composition and dynamics of the atmosphere, the planetary climate or the presence of natural satellites. The use of spectrophotometric light curves allows to achieve several levels of the atmosphere and follow the evolution of its main components.

We present the study of the modeled thermal emission of nine Earth-like planets, including variations on the albedo (Earth continental distribution, aquaplanet or snowball planet), the obliquity, the eccentricity of the orbit, the rotation rate (slow rotations and tidally-locked planets) and the presence of moons.

We have derived the particular characteristics of the light curves of this type of planets by the study of the influence of these parameters on the climate and on the thermal emission. The effective temperature, the albedo, the seasonal variations, the presence of warm and cold spots on the surface or the rotation rate of the planet can be inferred from thermal light curves. However, the detection of the rotation rate also depends on the conditions of the weather patterns such as cloud lifetimes or superrotating winds.

.Jean-Francois Lestrade• Observatoire de Paris, France

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*Steady-State Collisional Evolution Model and the DEBRIS Disk Survey*

We have confronted the predictions of the steady state collisional evolution model with the results of the searches for cold debris disks around AFGKM type stars conducted with Spitzer and, more recently, with the Herschel DEBRIS program.

We used a novel technique to determine the parameters of the disk population evolved with this model over the star ages in fitting, not the detection frequencies in these surveys, but the shape of the distribution of the fractional dust luminosities observed. In this approach, we stipulate that the initial disk mass distribution is bimodal and that only high-mass collisionally-dominated disks are detected.

The best determined parameter of the model is the diameter Dc of the largest planetesimals in the collisional cascade of the model. It ranges between 2 and 60 km, consistently for disks around both A- and FGK-type stars. It is remarkable that this range is consistent with the break found at around 30km in the Kuiper belt objects size distribution. This break separates the subpopulations of the largest primordial objects from the eroded planetesimals.

Finally, we make the assumption that the same disk population surrounds the M-dwarfs that have been searched and we study to what degree the apparently less frequent debris disks around this type of stars is consistent with the model.

Jessica Pericaud• University of Bordeux, France
*HD141569: Disk Dissipation Caught in Action*

30

Debris disks are usually thought to be gas-poor, the gas being dissipated by accretion or evaporation during the proto-planetary phases. HD141569 is a 5 Myr old star harbouring a famous debris disk, with multiple rings and spiral features in particular imaged in scattered light. The dust observations also reveal a central cavity of ~130 AU. Despite the apparently evolved status of the disk, large quantities of CO have been detected. Near-infrared observations of gas have revealed that the dust cavity is not devoid of gas, and by consequence that the gas and dust are not co-located.

I present here Plateau de Bure Interferometer observations mapping the 12CO(2-1) gas in HD141569 disk. We used the DISKFIT code to analyze the data and model them by fitting power-laws. It confirms that dust and gas are not co-located everywhere in the disk with the gas inner radius inferior to 60 AU and its outer radius being smaller than the dust one. In terms of modeling, the results indicate the gas is still optically thick and more massive than expected for a debris disk.

This study tend to show that HD141569 is an hybrid disk with a primordial gas component and secondary-made dust created by planetesimal collisions, and then is an interesting target to better understand the transition between early and evolved phases of the disks which give birth to planetary systems.

Jesus Maldonado• INAF-OAPa, Italy
*Analysis of M dwarfs Spectra and Search for Small Planets at the Galileo Telescope*

31

Within the framework of GAPS: Global Architecture of Planetary Systems, a long-term project at the Telescopio Nazionale Galileo, our team has started an observational monitoring of nearby, early-type, M dwarfs, using HARPS-N to search for small planets around low-mass stars. In this contribution we present a brief summary of the project status, as well as the efforts of our team to determine accurate stellar parameters for these stars taking advantage of the high-quality HARPS-N spectra.

Joao Bento • Macquarie University, Australia
*The RHEA Spectrograph*

32

The current limitations associated with detecting exoplanets using Radial Velocity (RV) measurements include temperature and pressure stability of spectrographs and efficient fibre scrambling. Additionally, an astrophysical fundamental limitation in the form of noise from stellar activity is becoming increasingly important. This is particularly true for giant stars, where the amplitude of pulsations is comparable to RV signals from hot-Jupiters. Asteroseismological analysis of long-baseline RV measurements is required to measure the intrinsic pulsations of the host star and de-correlate them to search for the planetary signals. This is impractical using large telescopes, but possible to do on bright stars with 0.2-0.4m class telescopes, provided they can be fitted with cheap high-resolution spectrographs. We present the current status of development and first observations of the Replicable High-Resolution Exoplanets and Asteroseismology (RHEA) spectrograph, an inexpensive compact single-mode fibre-fed spectrograph being developed at Macquarie University with the aim of serving as the basis of a series of spectrographs to be deployed on small telescopes for exoplanet and asteroseismological studies.

Johannes Sahlmann• ESA, *Spain*

*Astrometric Planet Search Around Southern Ultracool Dwarfs*

33

I will present the results obtained from the first two years of our ground-based survey of 20 nearby M8-L2 dwarfs using FORS2/VLT. The average astrometric accuracy is 150 micro-arcseconds and I will show how we use this data to determine trigonometric parallaxes with uncertainties of 0.1 mas, to discover tight ultracool binaries, and to constrain the occurrence of giant planets at intermediate separation around M8-L2 dwarfs.

John Moriarty• Yale University, USA

*Chemistry in an Evolving Protoplanetary Disk: Effects on Terrestrial Planet Composition*

34

The composition of planets is largely determined by the chemical and dynamical evolution of the disk throughout planetesimal formation and growth. To account for the evolution of the disk during planetesimal formation, we couple models of protoplanetary disk chemistry and dynamics with a model of planetesimal formation. We then follow the growth of these planetesimals into terrestrial planets with N-body simulations of late stage planet formation. We find that our model produces carbon enriched planets over a wide range of semi-major axes for disks that are initially enhanced in carbon (C/O > 0.8). Furthermore, we find that planetesimal formation in the outer disk leads to the depletion of oxygen, or equivalently, an enhancement of the C/O ratio in the disk. As the disk material is transported inwards, the C/O ratio will continue to be enhanced up to the point where carbon rich solids will condense out. This mechanism can produce carbon rich planets close to the star for disks with initial C/O ratios lower than 0.8. This suggests that if many of the known close in terrestrial exoplanets formed in situ, there are likely more carbon rich planets than initially thought.

Judit Szulagyi• Observatoire de la Côte d'Azur, France

*Accretion of Jupiter-mass Planets*

35

The core accretion model predicts runaway gas accretion phase for giant planets, which does not stop until the planet opened a deep gap after acquiring 5-10 Jupiter-masses. However, observational evidences show that this massive giant planets are rare in the universe. In order to solve this contradiction, we performed 3D hydrodynamical simulations of a Jupiter-mass planet in both isothermal and adiabatic settings. We were interested in understanding how the circumplanetary disk (CPD) acts as a regulator of the accretion process. In the isothermal simulation, we found that the ~90% of the mass accreted by the planet comes from the vertical inflow in the planetary gap; this inflow is part of a meridional circulation in the circumstellar disk. We distinguished among the different accretion mechanisms and uncovered that in the zero viscosity limit, the main mechanism allowing the CPD to lose angular momentum is the torque exerted by the star via the spiral density wave. In this limit, we found that Jupiter's mass doubling time is comparable to the photoevaporation timescale (i.e. half Myr), which could explain the observed variety of planetary masses, including the lack of very massive planets. This estimate, though, is uncertain, because isothermal simulations cannot approximate the CPD's mass. Thus, we further developed a hydrodynamic code to handle the energy equation, stellar irradiation and a simplified radiative transfer, in order to address the maximal mass of the CPD in the zero viscosity limit. The results and comparisons of both simulations will be presented at the conference.

Karin Öberg• Harvard-Smithsonian Center for Astrophysiscs, USA

*Snowlines in Protoplanetary Disks*

36

Planets form in disks around young stars. The details of the planet forming process, and the composition of the nascent planets depend on the physical-chemical structure of such disks. One set of important structural features are disk condensation fronts, or snow lines, of major volatiles; their locations and shapes are expected to affect grain growth, the bulk composition of forming planets at different disk radii, and the nature of the organic disk chemistry. We have explored the chemical effects of such snowlines through a combination of theory and spatially resolved observations of molecular emission in nearby disks. I will present some of the key findings, including the first chemical image of the CO snowline in a protoplanetary disk using ALMA. I will further discuss the implications of this and related results for planet and planetesimal compositions, including their organic content, in the Solar System and elsewhere.

Kate Su• Steward Observatory, University of Arizona, USA

*HD 95086 -- A Young Analog of HR 8799?*

37

HD 95086 is a young A8 star that possesses a large infrared excess, indicative of a massive debris disk, and a 5 Jupiter mass planet at the projected distance of 56 AU, revealed by direct imaging. Its disk was marginally resolved by Herschel and found to be inclined at 25 degree from face-on. Here we present detailed analysis of the disk SED and re-analysis of the resolved images. Our results suggest that the debris structure around HD 95086 is very similar to that of HR 8799: a warm (~170 K) belt, a cold (~60 K) disk, and an extended disk halo (up to ~400 AU). Using dynamical simulations with the disk parameters extracted from SED and imaging, we obtain further constraints on the possible orbital configurations of other unseen planets in the system.

Kevin Flaherty• Wesleyan University, USA

*Directly Measuring Turbulence in a Protoplanetary Disk using CO*

38

Turbulence within protoplanetary disks plays a crucial role in setting the temperature and density structure, as well as influencing the growth and migration of planetesimals. Despite its importance there are few observational constraints on its strength, leaving open the possibility that it may inhibit planetesimal growth by preventing dust grains from settling to the midplane or enhance planetesimal growth within localized turbulent vortices. Here we present a search for turbulence around the nearby Herbig Ae star HD 163296. Building on previous work that detected turbulence within this disk, we use ALMA data that can spatially resolve vertical structure, which is highly degenerate with turbulent broadening, providing stronger constraints on the vertical temperature profile than was previously available. This new data, combined with a Bayesian analysis of the parameter space, can put physically meaningful constraints on the strength of the turbulence within this system and its role in the planet formation process.

Kurt Liffman • CSIRO, Australia

*Magnetic Compression of the Inner Disc Region in Young Stellar Systems*

39

When the magnetic field of a young star interacts with a surrounding accretion disc, radial currents are generated within the disc, which then produce toroidal magnetic disc fields. The interaction between the radial current and toroidal field conspire to produce a Lorentz force that compresses the disc.

We suggest that this mechanism may be what is producing the "light house" effect seen in young stellar systems such as LRLL 31, where the infrared spectrum of LRLL 31 is observed to undergo unusual temporal changes in infrared flux between 5 and 40 microns. In particular, as the flux between 5 and 8.5 micron increases the flux between 8.5 and 40 micron decreases (Flaherty et al. 2011).

A possible explanation for this behaviour is that the young star is surrounded by a transition or pre-transition disc. In such a disc the inner regions are optically thick, as are the outer regions, but the middle disk region is optically thin. As a consequence, when the scale height of the inner disc is compressed then the outer disc is illuminated. Alternatively, when the scale height of the inner disc is not compressed then the outer disc is in shadow. It is by such a mechanism that observed "seesaw" behaviour in the infrared spectrum is produced. LRLL 31 is not unique in this regard and recent surveys have found more examples of this behaviour in other young stellar systems. We discuss how our "magnetic scale height" may be producing this effect.

Kyle Mede • University of Tokyo, Japan

*The CHARIS Data Extraction Software: Integral Field Spectroscopy at High Contrast*

40

I will present the design of a custom data extraction software package for the Coronagraphic High Angular Resolution Imaging Spectrograph (CHARIS) under development for the Subaru Telescope. Integral field spectrographs (IFSs) are the instrument of choice for high contrast imaging. With both spatial and spectral information, IFS data cubes can both suppress starlight to increase contrast beyond the limits of simple cameras, and directly measure exoplanet spectra. Current IFSs gain an order or magnitude or more in contrast from post-processing of the data cubes, making both hardware and software critical to their success. I will describe the data extraction software to reconstruct ~20,000 spectra from each raw detector readout, producing a 3-dimensional (x, y, lamba) data cube that will achieve a high level of spectrophotometric precision (~0.06 mag) for atmospheric characterization, astrometric precision (~3 mas) for orbital characterization, with a fast reconstruction (< 5 s) for focal plane wavefront sensing.

Direct imaging offers one of the only ways to take spectra of, and to characterize, young gas giant exoplanet atmospheres. A key goal for the field is to use high-contrast integral-field spectroscopy to detect, and understand, young analogs to the gas giants in the solar system. CHARIS has been design for these goals, and in combination with the AO188 and SCExAO adaptive optics systems, the suite of high contrast instrumentation at Subaru will form the premier high contrast imaging system. CHARIS will be added to the Subaru Telescope in late 2015.

Leslie Rogers • California Institute of Technology, USA

*Most 1.6 Earth-Radii Planets are not Rocky*

41

The Kepler Mission, combined with ground based radial velocity follow-up and TTV dynamical analyses, has revolutionized the observational constraints on sub-Neptune-size planet compositions. The results of an extensive Kepler follow-up program, which includes multiple Doppler measurements for 22 KOIs (Marcy et al. 2014), more than double the population of sub-Neptune-sized transiting planets with radial velocity mass constraints. This unprecedentedly large and homogeneous sample of planets with both mass and radius constraints opens the possibility of a statistical study of the underlying population of planet compositions. We focus on the intriguing transition between rocky exoplanets (comprised of iron and silicates) and planets with voluminous layers of volatiles (H/He and astrophysical ices). Applying a hierarchical Bayesian statistical approach to the sample of Kepler transiting sub-Neptune planets with Keck radial velocity follow-up, we constrain the fraction of planets that are dense enough to be rocky (as a function of planet radius). We show, with 95% statistical confidence, that the majority of 1.6 Earth-radii planets are too low density to be comprised of Fe and silicates alone. At larger radii, the constraints on the fraction of rocky planets are even more stringent. These insights into the size demographics of rocky and volatile-rich planets offer empirical constraints for planet formation theories, and guide the range of planet radii to be considered in studies of the occurrence rate of "Earth-like" planets.

Lisa Nortmann • Institut für Astrophysik, Germany

*Characterizing Hot Jupiter Atmospheres with Ground-Based Facilities*

42

Transiting planets are of particular interest for exoplanet science. During transit the upper atmospheric layers are penetrated by the host star's light enabling us to measure the atmospheric composition at the terminator region as a color dependent variation in the occultation depth. One of the biggest remaining challenges of multi-color transit observations is the removal of systematic noise signals. Such signals are frequently found to distort light curves of both ground-based and space-based origin. In many cases their source is not well understood. Our group uses the ground-based facilities ESO/VLT with the FORS2 instrument and the Spanish 10-meter telescope GranTeCan with the OSIRIS instrument to probe the atmosphere of hot Jupiters with the technique of multi object spectrophotometry. I will address our new findings regarding the source and nature of instrument specific systematics we found to commonly affect data taken with these two instruments. Furthermore, I will introduce our approach to the correction of these noise signals, which allows us to retrieve high quality results. As an example I will present the transmission spectra of the two hot Jupiters WASP-17b and HAT-P-32b which we obtained in the broad optical wavelength region between 500 – 1000 nm where hot Jupiter atmospheres are predicted to exhibit sodium, potassium, water and titanium/vanadium oxide absorption. The abundance of these atmospheric species is of particular interest, as they serve as good indicators for the prevalent temperature and can help to shed light on the mechanisms of heat re-distribution between the planet's day and night side.

Luca Matrà • Institute of Astronomy, Cambridge, UK
*Probing CO Gas in Debris Disks with ALMA*

43

The advent of ALMA has recently delivered detection of CO gas in debris disks, which were thought to be predominantly gas-poor objects. Its origin is still unconstrained: is it the product of collisions between cometary bodies? Does it represent a gaseous remnant of protoplanetary disks? In order to understand the role played by gas in both the disk dynamics and the planet formation process itself, searching for its presence in such relatively old systems is needed.
We therefore analysed ALMA Cycle-0 data of the nearby Fomalhaut debris ring searching for CO J=3-2 emission, and defined a rigorous way to achieve detection and model ALMA line data for debris disks.
In the Fomalhaut case, no emission is detected. We build a simple model to obtain an upper limit estimate on the total mass of CO in the ring, and show that the commonly adopted assumption of local thermodynamic equilibrium (LTE) should not hold at low densities typical of debris disks. This implies that determination of gas mass from CO line emission has to take into account the local gas density, as well as its temperature.
With this in mind, we set constraints on the CO mass present in the Fomalhaut ring, and discuss possible improvements through future ALMA observations.

Marco Rocchetto • University College London, UK
*A Double-Blind Spitzer/COS Survey to Constrain the Frequency of Circumstellar Debris at White Dwarfs*

44

We will present the results of a first unbiased Spitzer survey of a homogeneous and well-defined sample of 140 white dwarfs in search of infrared excesses compatible with the presence of circumstellar dust discs formed from the disruption of planetesimals. The stars were selected without any regard to atmospheric metal content but chosen to have 1) hydrogen rich atmospheres, 2) $17000 < T_{eff} < 25000$ K and correspondingly young cooling ages of 20-120 Myr, and 3) UV brightness for a corresponding HST COS Snapshot survey.
We find that four white dwarfs host a dust disc, three of which are previously known and one reported here for the first time, yielding a nominal 3% of white dwarfs with infrared excess in this range of post-main sequence ages. These stars largely descend from 2-3 solar mass, A-type stars and thus 3% is a firm lower limit on the fraction of such main-sequence stars that host rocky exoplanetary systems. Furthermore, our complementary HST observations indicate this fraction is likely to be roughly a factor of 10 higher, with the bulk of all circumstellar discs at white dwarfs remain hidden from current infrared detection methods. The presence of narrow and attenuated dust rings, and especially atmospheric pollution, corroborate this interpretation.

Mark Booth • Pontificia Universidad Católica de Chile, Chile
*Far Infrared and Sub-millimeter Imaging of HR 8799*

45

HR 8799 is well known for being the only star to host multiple planets discovered through direct imaging. HR 8799 also hosts a debris disc first discovered by IRAS. This disc was one of the few resolved by Spitzer showing that dust is present out to a few thousand AU. The Spitzer data also showed that there must be multiple components to the dust both inside and outside the orbits of the planets. Naturally, this system has been a prime target for observations from various telescopes in recent years. I will focus on the results of imaging with Herschel, ALMA cycle 0 and JCMT/SCUBA-2. The disc is found to be resolved at 70, 100, 160, 250 and 850 µm. The resolution of the Herschel data has allowed us to determine the inclination of the disc for the first time, showing it to be coplanar with the planets and star. Both Herschel and ALMA observations do not detect any clumpiness that might be expected due to interactions between the planets and the disc, implying that the eccentricity of the outermost planet is <0.1. Combined analysis of the spectral energy distribution and the resolved images presents new questions since the dust is seen to be distributed over a wide range of radii and yet only a narrow range of temperatures is seen.

Mark Hollands• University of Warwick, UK
*Evolved Planetary Systems Around Very Cool and Old White Dwarfs*

46

Metal-pollution of white dwarfs (WDs) are the signposts of evolved planetary systems. Rocky planetesimals venturing too close to the WD are tidally disrupted, forming a dust disc that is subsequently accreted by the WD. The photospheric abundances provide powerful insight into the chemical composition of the parent bodies.
We present a sample of 59 cool and old, strongly metal-polluted WDs identified from Sloan Digital Sky Survey (SDSS) spectroscopy. These stars evaded prior detection as the strong absorption lines in the blue part of their spectra dramatically alter their colours, mixing them into the colour space of intermediate-redshift quasars. In the atmospheres of most of these WDs we identify calcium, magnesium, sodium and iron, however their relative abundances vary significantly. The minimum masses that have been accreted regularly exceed those of the largest solar system asteroids. The coolest of these objects is below 5000 K, corresponding to a cooling age in excess of 7 Gyr. This provides a lower limit for how long ago rocky material began forming within the Galaxy, and, more generally, studying these old systems offers insight into terrestrial planet formation.

Mark Hutchison• Swinburne University, Australia
*Photoevaporation in Dusty Discs*

47

Small grains set the energy balance in a disc, particularly in the surface layers where the gas is susceptible to photoevaporation, i.e. the dispersal of the disc through winds created by stellar irradiation. The aerodynamic drag felt by dust due to outflowing gas competes with planet formation mechanisms by removing dust and impeding grain growth/settling in the disc midplane. Accurate simulations involving photoevaporation in dusty discs must therefore include proper treatment of both phases (gas+dust) along with an efficient treatment of radiative transfer. I will present recent developments on the dust evolution in photoevaporating discs, starting from simulating 1D simple systems and progressively going to 3D realistic discs.

Marta Bryan• California Institute of Technology, USA
*Quantifying the Effect of Massive Long Period Companions on the Formation and Evolution of Planetary Systems*

48

We are conducting a Doppler survey at Keck combined with NIRC2 K-band AO imaging to search for massive, long-period companions to a sample of 148 exoplanet systems detected using the radial velocity method. While large surveys have made it possible to understand the statistical properties of exoplanet populations, recent studies have focused on determining mass distributions and occurrence rates of transiting short period, low mass planets around individual Sun-like stars found by the Kepler mission. Many of these surveys are primarily sensitive to short-period planets, making it difficult to evaluate the role that a massive distant planetary or stellar companion might have on the formation and orbital evolution of the inner planets. These kinds of companions could stir up the protoplanetary disk, making the coalescing of material difficult, they could truncate the outer disk, shortening disk lifetime and planet formation timescales, or they could affect the evolution of inner planets via dynamical interactions, such as planet-planet scattering or the Kozai mechanism. Studying the differences between populations of planets with and without these companions presents a new opportunity to constrain mechanisms of planet formation and evolution. Here we present results from our radial velocity trend search for massive, distant companions in RV-confirmed exoplanet systems. This program is complementary to the studies of companion occurrence rates in hot Jupiter systems being presented by Henry Ngo and Danielle Piskorz.

Mathieu Guenel• CEA, France
*Unraveling Tidal Dissipation in Gaseous Giant Planets*

49

Tidal dissipation in planetary and stellar interiors is one of the key mechanisms that drive the evolution of planetary systems, especially for planets orbiting close to their host star. Moreover, tidal dissipation depends on the internal structure and rheology of the involved bodies. In this work, we focus on the tidal response of gaseous giant planets using a simplified bi-layer model consisting of a homogeneous rocky/icy core surrounded by a homogeneous fluid convective envelope. In the cases of Jupiter-like and Saturn-like planets, we compare the frequency-averaged strengths of the viscoelastic dissipation occurring in the central solid region and the damping of inertial waves by turbulent friction occurring in fluid layers as a function of the size and the mass of the core. We find that the two distinct tidal dissipation reservoirs are generally of the same order of magnitude. This demonstrates that tidal dissipation in giant planets must be examined from their centre to their surface. In a near future, we would apply such a method to icy giant and telluric planets.

Matias Jones • Centre for Astro-Engineering, Pontificia Universidad Católica de Chile

*The Peculiar Properties of Planets Around Giant Stars*

50

More than 50 exoplanets have been detected around giant stars, revealing different properties when compared to planets orbiting solar-type stars. In particular, they are super Jupiters and are not found in orbits interior to ~0.5 AU.
In 2009 we started a RV search for planets around giant stars, aimed at studying the population of close-in planets and how their orbital and physical properties are influenced by the host star evolution.
In this talk I will present the results from our project, highlighted by the detection of several giant planets and a highly eccentric brown dwarf in the "desert".
I will also review the peculiar properties of planets orbiting evolved stars, and I will discuss about different scenarios that might explain these observational results.

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Matthew Kenworthy • Leiden Observatory, Netherlands

*Analysis and Modeling of a Giant Transiting Multiple Ring System around the Substellar Companion J1407b*

51

In May 2007 the nearby young (17 Myr) pre-MS star J1407 underwent a series of deep complex eclipses that lasted over 60 days. These eclipses were interpreted by Mamajek et al. (2012) to be caused by a giant ring system of up to 60 million km in diameter surrounding an unseen substellar companion, J1407b. A re-analysis of the photometry shows structure down to timescales of 1 hour, consistent with the movement of ring edges across the diameter of the stellar disk. We present our model of this giant exo-Saturn ring system, showing how we can simultaneously solve for the geometry of the ring system and the detection of over 20 individual rings. The presence of highly structured multiple rings is a signpost of the presence of exomoons. Future transits of this ring system will provide a unique observing opportunity to study a young ring system in formation.

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Matthew Payne •Harvard-Smithsonian Center for Astrophysics, USA

*Symplectic Integration & Circumbinary Satellite Stability*

52

We report on our development of a highly accurate symplectic integration system which (a) works in jacobi coordinates, and (b) simultaneously calculates the evolution of the tangent equations. This enables us to rapidly and accurately integrate (symplectically) arbitrary system configurations (e.g. planets in multi-stellar systems) while rigorously investigating their stability via measures of the Lyapunov exponent (and related MEGNO indicators).
We demonstrate this integration scheme by mapping out the possible stable configurations of planet-satellite system in circumbinary orbits around a pair of stars, and illustrate the implications for known Kepler circumbinary planets.
We go on to illustrate further novel applications of our integrator, including to the evolution of evolved planetary systems around white dwarfs.

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Mercedes Lopez-Morales• Harvard-Smithsonian Center for Astrophysics, USA

*ACCESS: The Arizona-CfA-Catolica Exoplanet Spectroscopy Survey*

53

The Arizona-CfA-Catolica Exoplanet Spectroscopy Survey (ACCESS) is an international, multi-institutional consortium with members from the Harvard-Smithsonian CfA, the University of Arizona, Pontificia Universidad Catolica in Chile, MIT and UC Santa Cruz and the Carnegie Institution. The goal of ACCESS is to observe about two dozen planets covering a wide range of mass, radius, atmospheric temperatures and energy irradiation levels, with two main scientific goals: 1) to obtain, for the first time, a uniform sample of visible transmission spectra of exoplanets, allowing the study of their atmospheric characteristics as a statistically significant sample, and 2) to mature the technique of ground-based observations of exoplanetary atmospheres for future observations of small planets. Here we describe ACCESS and its first science results.

Mihkel Kama• Leiden Observatory, Netherlands
*The Carbon Budget in Protoplanetary Disks: Observations, Modeling and the Connection to Planets*

54

The carbon abundance in the Sun and other Solar System objects differs. Improving measurements will soon provide similar comparisons for extrasolar planets and their stars. To understand the origin of planetary and stellar abundance differences, and to relate the abundance pattern of a planet to its formation history, we must study the gas and solid budget of carbon in protoplanetary disks. Some of the best probes of gaseous carbon in disks are lines of atomic carbon and carbon monoxide. We present the results of an APEX survey of [CI] and CO towards several dozen disks. Comparing with models created with the DALI code (Bruderer et al.), we confirm trends of a low volatile carbon abundance on large radial scales. We also present the first deep follow-up observations of [CI], aiming to provide the first confident detections of atomic carbon in disks. We also show the first analysis of C2H follow-up data.

Min-Kai Lin • CITA, Canada
*Gap Formation and Stability in Non-Isothermal Disks*

55

It has been established that disk-planet interaction can lead to the formation of large-scale structures in protoplanetary disks, such as disk vortices, because of hydrodynamical instabilities of gap edges. Indeed, this may explain recent observation of asymmetric dust distributions in transition disks. However, models thus far have employed nearly-isothermal disks, whereas the theory of the edge instability was in fact developed for adiabatic disks. We generalize the study of planetary gap stability to non-isothermal disks by including an energy equation. We present customized 2D numerical simulations of disk-planet interaction with parametrized cooling, and use the simulations to study both the linear and non-linear evolution of planetary gap edges. We find that increasing the cooling timescale generally favors the instability, resulting in longer vortex lifetimes. We suggest this is attributed to entropy generation by planet-induced spiral shocks.

Nicholas Stone • Columbia University, USA
*Evaporation and Accretion of Extrasolar Comets Following White Dwarf Kicks*

56

Several lines of observational evidence suggest that white dwarfs receive small birth kicks due to anisotropic mass loss. If other stars possess extrasolar analogues to the Solar Oort cloud, the orbits of comets in such clouds will be scrambled by white dwarf natal kicks. Although most comets will be unbound, some will be placed on low angular momentum orbits vulnerable to evaporation or tidal disruption. The dusty debris from these comets will manifest itself as a debris disk temporarily visible around newborn white dwarfs; examples of such disks may already have been seen in the Helix Nebula, and around several other young WDs. Future observations with the James Webb Space Telescope will distinguish this hypothesis from alternatives such as a dynamically excited Kuiper Belt analogue. If interpreted as indeed being cometary in origin, the observation that ~15% of young WDs possess such disks provides indirect evidence that low mass gas giants (thought necessary to produce an Oort cloud) are common in the outer regions of extrasolar planetary systems. Hydrogen abundances in the atmospheres of older white dwarfs can, if sufficiently low, also be used to place constraints on the joint parameter space of natal kicks and exo-Oort cloud models.

Nicolas Cuello • Centre de Recherche Astrophysique de Lyon, France
*Photophoresis Effects in Protoplanetary Disks: a Numerical Approach*

57

It is thought that planets form in the inner regions of protoplanetary disks (PPD) about 1-10 AU. However, the migration of solids, in some cases sending them in a very short time onto the star, is a problem for planet formation, known as the radial-drift barrier. It is crucial to overcome this major difficulty in order to build up planet cores next to the star. Several effects have been proposed to invert the radial drift of the planetesimals (magnetic breaking, dead-zones, meridional flow, turbulence, particle traps, etc...). In this work, we explore the star radiation effect on the inner regions of PPD, namely photophoresis. It is a very promising phenomenon which has been poorly explored from the numerical point of view.
Based on recent experiments of Duermann, Wurm and Kuepper, photophoresis (i.e. the thermal creep induced by the star irradiation) seems a good candidate. Indeed, they showed that its effects could revert the inward motion of meter-sized planetesimals at 1 AU in the disk. By means of a semi-analytical model, it can be shown that this force depends on the total size of the grain and on its porosity. We include this effect in our two-fluid (gas+dust) SPH code in order to explore whether or not this effect can break the radial-drift barrier. We run a series of numerical simulations for various disk configurations and grain sizes to assess its impacts on dynamics and growth.

Nienke van der Marel • Leiden Observatory, Netherlands
*Planet Formation in Action: the Role of Dust Trapping in Transitional Disks*

58

Planet formation by dust coagulation in protoplanetary disks is one of the long standing problems in disk evolution theory. The dust growth process is hindered by collisional fragmentation and rapid inward radial drift. A possible solution in dust evolution theory is dust trapping in local pressure maxima in the disk, where dust particles pile up and grow. Transitional disks with large inner dust cavities have been suggested to contain these dust traps. I present the results of our ALMA Cycle 0 program imaging Oph-IRS48 in 12CO(6-5), C17O(6-5) and the 0.45mm continuum. The 0.2″ spatial resolution completely resolves the cavity of this disk in the gas and the dust. Using our physical-chemical modeling tools we find that the gas distribution is consistent with a Keplerian gas disk with two drops in the radial surface density profile at 20 and 60 AU. These drops directly imply the presence of companions in the disk. Similar to the gas, the micrometer-sized dust grains follow a large ring-like structure. On the other hand, the ALMA continuum emission, tracing the millimeter-sized dust, reveals an unexpected huge asymmetry at 60 AU radius. The combination of the gas and dust distribution indicates that the dust trapping mechanism is at work in this disk: at the edge of the outer density drop is a pressure bump, which traps the millimeter dust. Also other transitional disks observed with ALMA show hints of dust trapping. I will present the most recent analysis of these dust traps and discuss the implications.

Olja Panic • Institute of Astronomy, Cambridge, UK
*Five Steps in the Evolution from Protoplanetary to Debris Disks*

59

The protoplanetary discs seen around Herbig Ae stars eventually dissipate leaving just a tenuous debris disc, comprised of planetesimals and the dust derived from them,as well as possibly gas and planets. This paper uses the properties of the youngest (10-20 Myr) A star debris discs to consider the transition from protoplanetary to debris disc. It is argued that the physical distinction between these two classes should rest on the presence of primordial gas in sufficient quantities to dominate the motion of small dust grains. This motivates an observational classification based on the dust emission spectrum which is empirically defined so that A star protoplanetary discs require disc to star flux ratios >2 at 12micron and >300 at 70micron. However, we note that flattened protoplanetary discs are indistinguishable from bright debris discs with any scheme relying on dust emission.

We also proposed that a useful hypothesis to test is that the planet and planetesimal systems seen onthe main sequence are already largely in place during the protoplanetary disc phase, but areobscured by the rest of the disc, with the alternatives being that these are set during therelatively short dispersal phase, or that the planetary system is in a constant state of fluxnuntil it is frozen at the epoch of disc dispersal.

Rafael Brahm • Pontificia Universidad Católica de Chile, Chile
A set of Automated Pipelines for Echelle Spectrographs Developed for the Follow up of Planetary Transit Candidates from the HATS

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A key task in the detection of exoplanets coming from transit surveys is the rejection of false positives and the confirmation of the true planets by measuring the Keplerian radial velocity signal of the host. Due to their high resolving power and wide spectral coverage, echelle spectrographs have proven to be a powerful tool for these goals. Here we present a homogeneous set of fully automated reduction pipelines for a large number of echelle spectrographs. Besides optimal extraction and wavelength calibration of the spectrum, these pipelines provide measurements of high precision radial velocities, bisector spans and stellar parameters. As an example of their performance, we have achieved a long term accuracy of ~9 m/s for the CORALIE spectrograph and ~7 m/s for the FEROS spectrograph as gauged by monitoring velocity standard stars for a period ~3 years

Richard Schwarz • Institute for Astrophysics, Austria

*Dynamics and Observational Prospects of Co-Orbital Planets in Double Stars*

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In the quest for new exoplanets close, eclipsing binaries are promising candidates because many lie in the CoRoT and Kepler discovery space. In general we distinguish three dynamical types of motion for extra-solar planets in binary star systems:
(i) S-Type: A planet orbits one of the two stars.
(ii) P-Type: A planet stays in an orbit around both stars.
(iii) T-Type: A planet may orbit close to one of the equilibrium points L4 or L5.
Our work is dedicated to the dynamics and the theory of observations of planets in T-Type configurations in binary star systems. With the help of stability studies we want to identify regions in the orbital parameter space where possible Trojan planets can have stable orbits and may be observed. This will be realized via investigations of eclipse timing variations (ETV). With the ETVs we will show whether it is possible to detect planet induced perturbations in the transit signal of the secondary star.

Rik van Lieshout • Astronomical Institute Anton Pannekoek, University of Amsterdam, Netherlands

*Physical Models for the Dusty Tails of Evaporating Planets*

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Two exoplanet candidates that have recently been discovered with the Kepler mission, KIC 12557548b and KOI-2700b, exhibit transit signals whose shapes suggest that they are accompanied by comet-like dust tails. Since the dust grains in the tails likely originate in the evaporating surfaces of the planets, these objects offer a unique chance to probe the interior of small exoplanets.
The precise morphology of the transit signals can be used to put constraints on the composition of the grains in the dust tails, since the evolution of the grains is dictated by material-dependent optical and thermodynamical properties.
We self-consistently model the dynamical and size evolution of dust grains released from the planet, by numerically solving the equations of motion and sublimation.
We use a radiative transfer code to compute synthetic light curves from the resulting steady-state dust distributions, and compare these with the phase-folded light curves of the two candidates discovered so far.

Roi Alonso • Instituto de Astrofísica de Canarias, Spain

*A Search for Transits on Cool White Dwarfs*

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We know of indirect evidences for remnants of planetary systems around white dwarfs (WDs), and the first Earth-mass objects outside our Solar System were found around a pulsar back in 1992. The small size of cool white dwarfs and their close-in "habitable zones" would make a transiting planet a unique laboratory to test the capabilities of the transmission spectroscopy technique to characterize exo-atmospheres. It has been suggested (Loeb & Maoz 2013) that a transiting planet around a WD could be searched for biomarkers using JWST. We have started a search for transiting planets around cool WDs (<7000K) using several 1-m class telescopes in summer 2013. Our goal is to observe for at least 8h a sample of 500-700 WDs before the JWST launch. We will present the current status of the survey and our sensitivity limits.

Scott Barenfeld • California Institute of Technology, USA

*Empirical Limits on Radial Velocity Planet Detection for Young Stars*

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We present initial results of a program to measure precise radial velocities and chromospheric activity levels for stars younger than the Sun. Using a sample of ~150 solar-type stars, we establish an empirical relationship between chromospheric activity and radial velocity "jitter". The floor of this relationship, which increases with increasing stellar activity, limits the minimum planet mass detectable around young stars to values higher than those corresponding to the instrumental limit. For stars younger than ~1 Gyr, typical levels of activity-induced jitter limit the sensitivity of radial velocity detectable planets to ~Neptune mass companions or larger, while at 0.1 Gyr the limit is to ~Saturn mass companions.

Scott Thomas • Institute of Astronomy, Cambridge , UK
*Improving our Knowledge of Exoplanetary Interiors through a Refined Water Equation of State*

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We have entered an era where planets at smaller and smaller radii are able to be found and characterized. A growing area of interest is exoplanetary interior modeling: using mass and radius measurements, these models allow us to place constraints on the planets' interior compositions. One important piece of information required for interior models is the pressure-temperature-density relation of various minerals, or "equation of state". Most authors use simple equations of state, often based on extrapolations of low-pressure experimental data. This is driven partially by the lack of available experimental information and partially by the desire to simplify the models, so this approach often neglects temperature dependence. While this produces only small changes in the bulk parameters of the system, more accurate equations of state are important when we build thermal structure models to understand the thermal evolution of planets. This is especially relevant for planets containing large fractions of water, which has a rich phase structure with strong temperature dependence. We survey the H2O equations of state used in exoplanetary interior studies to date, and compile a fully temperature-dependent H2O equation of state in the region relevant to planetary interior pressures and temperatures. We include data from a variety of sources, including experimental measurements for familiar phases like vapour, liquid and low-pressure ice; experimentally-verified quantum molecular dynamics simulations; and theoretical calculations at extreme temperatures. Using this, we examine the internal structure and evolution of planets containing H2O, including the effects of irradiation during their evolution and possible migration.

Sebastian Marino • Universidad de Chile, Chile
*Image Synthesis of the gap in HD100546 with Sparse Aperture Masking*

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HD100546, an Herbig Ae/Be star at a distance of 100 pc, is surrounded by a prominent circumstellar disk. A gap in the radial profile of the dust and gas surface densities has been inferred from SED and line profile modeling. This gap is 10AU or 0.1arcsec in radius, and its existence is thought to be due to dynamical clearing by a massive protoplanet. We report on observations at 3.81um of HD100546, obtained with NACO+VLT Sparse Aperture Masking. Using the MIRA image synthesis package, we have imaged a ring at a radius of ~10 AU. We performed different regularization methods obtaining the same results. We also report on a comparison with radiative transfer predictions based on the SED parametric models.

Sebastian Perez • Universidad de Chile, Chile
*Inferring Protoplanetary Masses from Resolved ALMA Molecular Gas Emission*

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Inner cavities and annular gaps in circumstellar disks are thought to be signposts of the process of giant planet formation.  The mass and orbits of these embedded giant planets determine the way how these cavities' walls are shaped. We aim to constrain the protoplanetary companion mass and disk parameters by comparing ALMA molecular gas images with hydrodynamical models. We want to exhaust the capabilities of 2D hydrodynamical simulations to extract planet(s) mass(es) and location(s) in transition disks.  In this conference, we will present the results of our efforts to couple hydro simulations with a 3D radiative transfer code to model resolved ALMA observations of protoplanetary disk's gas.

Simon Grimm • Institute of Physics, University of Zürich, Switzerland
*GENGA: a GPU Code for Planet Formation and Planetary System Evolution*

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We present GENGA, a GPU implementation of a hybrid symplectic N-body integrator, designed to integrate planet and planetesimal dynamics in the late stage of planet formation. It can also be used for high accuracy integration of the n-body problem, for example to study the long term stability of planetary systems.

GENGA can be used with three simulation modes: Integration of up to 2048 interacting massive bodies, integration with up to a million test particles, or simultaneous parallel integration of more than 100'000 individual planetary systems. I will also discuss the accuracy of the  code and show its limitations. Especially the complex treatment and outcomes of close encounters between planets or planetesimals.

We present two applications of GENGA: Firstly, the dynamics of planetesimals and the late stage of rocky planet formation due to planetesimal collisions. And secondly, a dynamical stability analysis of an exoplanetary system with an additional hypothetical super earth, which shows that in some multiple planetary systems, additional super earths could exist without perturbing the dynamical stability of the other planets (Elser et al. 2013).

Stanimir Metchev • University of Western Ontario, Canada 69

*A New Census of the Faintest Solar Neighborhood Asteroid Belts from WISE*

We present a sensitive search for WISE W3 (12 micron) and W4 (22 micron) excesses from warm optically thin dust around Hipparcos main sequence stars within 75 pc from the Sun. By employing WISE photometry at shorter wavelengths, W1 (3.4 micron) and W2 (4.5 micron) for contemporaneous measurements of the stellar photospheres, we attain optimal sensitivity to >10 micron excesses. We further derive and apply corrections to the fluxes of saturated stars, and are thus for the first time able to detect small excesses even around bright solar neighborhood stars in WISE.

Our analysis results in a 45% increase of the number of stars with warm dusty excesses within 75 pc of the Sun, even in the light of numerous recent studies on WISE. In particular, we identify 220 Hipparcos debris disk-host stars within 75 pc, for 108 of which we present the first detection of a debris disk at any wavelength. Our findings also include five new stars with tenuous but significant W3 excesses, adding new members to the small population of known exozodi within 75 pc. This substantial expansion in the solar neighborhood debris disk census allows increasingly accurate analyses of the correlations between stellar, debris disk, and exoplanetary properties.

Stefano Facchini • Institute of Astronomy, Cambridge, UK 70

*External photoevaporation imprints in protoplanetary discs*

Stars are likely to form in groups and clusters. Such environments can significantly affect the evolution of the protoplanetary discs associated with the new-born stars. In relatively small groups ($N > 50$) FUV radiation from the most massive stars permeates the young association, with typical intensity values $G_0 = 30 – 3000$ Draines. The radiation interacts with the gaseous discs heating them up to few hundred Kelvin. Such high temperatures generate a pressure-driven gaseous wind flowing from the discs outer edge. If the mass loss rates are significant, they can affect the secular evolution of the disc, and consequently inhibit planet formation. We have built a new 1D model computing the steady-state radial structure of the flow by solving the hydrodynamical equations in a quasi – spherical geometry. The temperature is computed via the 3D-PDR code, and coupled with the hydro equations. We found new solutions for the wind's steady-state radial profiles, as a function of stellar mass, disc radius and FUV intensity. We obtain mass loss rated for a large sample of discs outer radii and G0 values. Large discs ($R=200$ AU) show high mass loss rates ($> 10^{-8}M_\odot /$yr) even for a very low FUV flux ($G_0=30$). Moreover, we couple the dusty component to the gaseous one via dragging terms, and we obtain the radial surface density profile of the dust as a function of grain size. The wind is found to be strongly dust-depleted in the large ($>0.2\ \mu$m) grains tail of the distribution. This mechanism could therefore explain discs with an observed smaller dust extent with respect to the gaseous component.

Stephen J. Mojzsis • University of Colorado, USA 71

*A Radiogenic Heating Evolution Model for Cosmochemically Earth-like Exoplanets*

Exoplanet discoveries have generated diverse models of plausible "terrestrial-type" planetary interiors and tectonic regimes. Severe limitations of observable properties require many assumptions about the characteristics of these planets. We present the output of an analytical galactic chemical evolution (GCE) model that constraints one of those properties: radiogenic heating. Earth's radiogenic heat generation has evolved since its formation, and the same applies to exoplanets. To make these predictions, we have integrated a GCE model with cosmochemical data for our solar system. Our simulation of the chemical evolution of the interstellar medium in the solar annulus fits the model to the chemistry of our solar system at the time of its formation, and applies the carbonaceous chondrite/Earth's mantle ratio to determine the chemical composition of cosmochemically Earth-like exoplanets. In doing so, predictions of exoplanet radiogenic heat productions as a function of age can be derived. The later a planet forms in galactic history, the less radiogenic heat it begins with; however, due to the declining nature of radioactive decay, today, old planets have lower heat outputs per unit volume than newly formed worlds. Due to its long half-life, 232Th continues to provide a small amount of heat in ancient planets, while 40K dominates heating in young ones. By constraining the age-dependent heat production in exoplanets, we can infer that younger, hotter terrestrial planets are more likely to be geologically active. In the search for Earth-like planets, the focus should be made on stars not much older than the Sun.

Tim Pearce • Institute of Astronomy, Cambridge, UK

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*Dynamical Evolution of Eccentric Planets and Debris Discs*

We examine the dynamical evolution of a single planet and a debris disc of equal or lower mass, if the planet is on an eccentric orbit bringing it close to or within the disc. An example of this scenario could be the aftermath of a planet – planet scattering event. By running a large suite of n-body integrations and combining these with theoretical results, we characterise the general evolution of such a system for a wide range of initial conditions. We find that there are two possible outcomes if the planet is more massive than the disc; either the inner region of the disc is removed and the remaining debris becomes eccentric and apsidally aligned with the planet, or the entire disc is ejected. In both cases the planet's orbital elements undergo only minor changes, and we provide criteria to predict which of these outcomes will occur. We also find that if the planet and disc are of comparable mass then the former may undergo significant eccentricity damping and migration, and that the disc appearance differs considerably from the previous case. The overall shapes of both sets of discs and the density variations within them are characterised, as are the important timescales. The evolution of the planet's orbit is also quantified in both cases. The results of this study may be used to predict the general outcomes of such a scenario, or to infer the properties of an unseen eccentric planet from features observed in debris discs.

Tomas Stolker • Astronomical Institute Anton Pannekoek, University of Amsterdam, Netherlands

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*A New Radiative Transfer Code For Exoplanet Atmospheres*

High-contrast imaging and spectroscopy of exoplanets will happen more frequently with upcoming instruments for ground based telescopes and space missions. Both the thermal infrared and the reflected optical stellar light carry valuable information about the structure and composition of the atmosphere of an exoplanet. We are developing a Monte Carlo radiative transfer code which allows us to quantitatively understand the physical and chemical nature of varies types of exoplanet atmospheres. This code simulates the radiative transfer of both the stellar light and thermal infrared through an inhomogeneous exoplanet atmosphere from which we can calculate its temperature structure. In addition, observable output results include images, spectral energy distributions and polarization signals of the simulated exoplanets. Polarimetry is a powerful technique that enhances the contrast between a star and an exoplanet. It also allows for the characterization of exoplanets since a polarization signal is sensitive to the structure and composition of a planetary atmosphere. Therefore, starlight that is scattered by an exoplanet atmosphere will have a certain degree of linear polarization as a function of wavelength and phase angle. This poster will show some of the results of these radiative transfer calculations and its application for the interpretation of future observations

Torsten Loehne • Astrophysical Institute, Friedrich-Schiller-Universität Jena, Germany

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*Approaching the Origin of Warm Components in Resolved Cold Debris Discs*

Observations at optical and far-infrared wavelengths reveal the presence of debris discs around at least 20 percent of stars across the main sequence. For a growing number of observed systems with debris discs, spatial resolution and densely sampled SEDs allow us to more tightly constrain their properties. Being remnants of the planet formation process, debris discs consist of (unobservable) planetesimals and collisionally replenished dust. To link observational data with potential scenarios for their formation and dynamical history, we performed in-depth collisional modeling for a handful of discs (e.g., HD 207129, HIP 17439, q1 Eri). The simulations start from a distribution of planetesimals and follow the production and loss of material in a collisional cascade, including the dynamical effects of direct radiation pressure and drag forces. One characteristic feature common to the discs is the presence of additional emission closer to the star, incompatible with a pure ring-like disc. We show that this emission can be explained, to a varying degree, by (a) drag of dust into an inner region devoid of planetesimals, (b) an extended, self-stirred and self-cleared debris disc, and/or (c) a separate inner disc. In all cases, the models suggest low dynamical excitation, i.e. discs that are quiescent rather than very active.

Volker Hoffmann • Institute of Physics, University of Zürich, Switzerland
*Chaos and Predictability in Terrestrial Planet Formation Simulations*

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The formation of terrestrial planets by the collisional growth of planetesimals is a stochastic process. We show that practically identical initial conditions result in a wide array of final planetary configurations. This highly chaotic behaviour questions the predictability of different scenarios for the formation and evolution of our solar system and planetary systems in general. We present two sets of numerical experiments that quantify this behaviour.

Firstly, we demonstrate that simulations with slightly displaced particles are completely divergent after ~500 years, irrespective of initial displacement, particle number, and code accuracy. Secondly, we show final planetary configurations of initially similar simulations with and without giant planets after evolving them for 146 Myr. We find that the same simulations including giant planets tend to generate higher mass planets at lower semi-major axes than simulations without gas giants. This prediction can be tested with forthcoming observational programs.

Yasuhiro Hasegawa• Institute of Astronomy and Astrophysics, Academia Sinica, Taiwan
*Planet Traps and Stellar Metallicity: Application to the Planet-Metallicity Relation and the Formation of First Gas Giants*

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Stellar metallicity is one of the fundamental parameters for planet formation in protoplanetary disks. We present a statistical analysis for planetary populations generated by the combination of the core accretion scenario with planet traps at which rapid type I migration is halted. We compute the planet formation frequency (PFF) and the planetary core mass, as a function of metallicity ([Fe/H]). The analysis is applied for three major populations inferred from the exoplanet observations: hot Jupiters, exo-Jupiters that are densely populated around 1 AU, and low-mass planets such as super-Earths. We show that the PFFs for both types of Jovian planets correlate positively with metallicity whereas the low-mass planets form efficiently for a wide range of metallicities. We find that these trends originate from the planetary core mass: the core mass of both kinds of Jovian planets increases steadily with metallicity while that of the low-mass planets is almost constant. These behaviors on the core mass define transition metallicity (TM) above which the core mass of Jovian planets exceeds that of the low-mass ones, and hence gas giant formation becomes efficient. We demonstrate that the properties of TM depend on the critical core mass that initiates gas accretion onto the cores. Comparing the radial velocity observations, our results show that the typical critical core mass for observed exoplanets is likely to be about 5 Earth-masse. Finally, we apply the calculations to metal-poor stars, and find that the critical metallicity for forming first gas giants is likely to be [Fe/H] = -1.2.

Zachary Draper• University of Victoria, Canada
*λ Boo Phenomenon Caused by Debris Disk Accretion?*

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λ Boo stars are Population I, A0-F3 stars with strongly depleted Fe peak elements abundances but relatively normal solar abundances of C, N, O, and S. Since they are only 1% of field stars and exhibit a variety of ages, transient mechanisms external to the photosphere have been proposed to explain the abnormal surface abundances. These include ISM interactions or accretion from a debris disk. In these external mechanisms the gas and dust are deferentially accreted, such that the surface will appear depleted in Fe-peak metals but rich in gases. With Herschel observations it was found that 8/8 of λ Boo stars observed show an excess emission at 100 to 160 microns. λ Boo, ρ Vir, and HD31295 are resolved and well modeled by a cold debris disk. Other unresolved sources are consistent with the presence of a cold debris disk due to the fact that 0.1 micron dust grains typical of the ISM would reach the equilibrium temperature observed at much larger scales in a bow shock than a debris disk. We compare stellar abundances from high-resolution spectroscopy and disk properties inferred by sub-mm emission to determine if there is any correlation that would further support debris disks as the cause of the λ Boo phenomenon.