Suzanne Aigrain (Oxford) & Jayne Birkby (Amsterdam)

University of Oxford

A017

Beyond the cross-correlation method: Gaussian Processes for high-dispersion spectroscopy of exoplanet atmospheres

Time-series high-dispersion spectra of planet-host stars, taken during and around a transit, or around superior conjunction, are a powerful probe of planetary atmospheres, which nicely complements the information that can be extracted from lower-dispersion observations of transits and eclipses. Typically, the planet's signal is detected by cross-correlating the spectra with a template spectrum corresponding to a single molecule. This yields a detection of the relevant molecule as well as a direct measurement of the planet's orbital velocity and, in some cases, its rotation rate and/or an estimate of the speed of high-altitude winds in the planet's atmosphere. However, as the cross-correlation method doesn't extract the planet's spectrum itself, direct measurements of abundances are challenging, and unexpected but detectable spectral features could be missed. Uncertainty estimates are also problematic with the cross-correlation approach. In this poster, we investigate an alternative approach, which consists in modelling the planet's spectrum as a Gaussian Process. This enables us to fit for the orbital velocity directly, making it more straight-forward to estimate the significance of the detection. It yields a direct estimate of the planet's spectrum, which can be used for atmospheric retrieval. We will present preliminary tests of this approach on the CRIRES observations of the dayside of HD189733b, first published by Birkby et al. (2013), which were originally used to detect water vapour absorption. As this new approach makes no assumption about the shape of the planet's spectrum, it is less sensitive overall, and we cannot recover the original detection, but we do detect injected H_2O signals down to three times the nominal planet-to-star flux ratio.

David Armstrong

University of Warwick

A059

Automatic planet candidate vetting with NGTS

Surveys for transiting planets produce candidate signals at a far faster rate than true planets. Planets in the sample must be selected for further follow-up observations, while avoiding spending limited telescope time on false positive signals such as contaminating eclipsing binaries and instrumental artefacts. This process typically involves human inspection, a time intensive task with hard to quantify biases. Recent methods have turned to the field of machine learning in an attempt to automate the process, demonstrating the plausibility of several methods on surveys such as Kepler and K2. Applying these techniques to ground based surveys is challenging, due to the complications of window functions and increased systematic noise. I will present a new public code, widely applicable to ground and space based surveys, demonstrating the improvements in efficiency and reliability found when applying the method to NGTS data. Efficiently selecting the best candidates will minimise time wasted following up false positive signals, while in future allowing rigorous determination of planet occurrence rates through limiting human participation in the planet search pipeline.

Adrian Barker

University of Leeds

A013 – ORAL PRESENTATION

Tidal dissipation in giant planets containing regions of layered convection

Tidal interactions play an important role in the evolution of the orbits and spins of extrasolar planets, and in the migration of the satellites of Jupiter & Saturn. The mechanisms responsible for tidal dissipation remain poorly understood, but it has been recognised that they will depend strongly on the internal structure of the planet. Recent observations from the Juno mission are consistent with giant planet interior models that contain gradients in heavy elements — these could be sufficient to inhibit ordinary convection, but allow double-diffusive convection. This is thought to produce a staircase-profile for the density, in which convective layers are separated by very thin stably-stratified interfaces. I will present recent calculations exploring the effects of a region of layered convection on tidal dissipation. The rates of tidal dissipation can be significantly enhanced compared to a purely convective medium for astrophysically-relevant tidal frequencies. This highlights the importance of considering such density structures for tidal dissipation in giant planets, and the implications of these results will be discussed.

Rob Barnsley

University of Oxford

A011

Can the European ELT detect super-Earths? Measuring the contrast limit in a laboratory experiment: an update on progress

The European Extremely Large Telescope (E-ELT) is a revolutionary new ground-based telescope with a 39-metre main mirror, currently under construction in the Atacama desert in Northern Chile. One of the main scientific goals for E-ELT is to directly image and characterise Earth-like planets around Sun-like stars, where life could exist in the habitable zone. This will be made possible with a dedicated planetary camera and spectrograph, ELT-PCS.

Using a combination of XAO and coronography, ELT-PCS will achieve a contrast ratio of the order of 10^{-6}. The remaining factor of a thousand required to meet the TLR will have to come from optimised instrument design and novel data processing techniques.

The former is the focus of this paper, where we discuss the progress made on the ongoing development of a spectrograph test bench that will interface to ESO's High-Order Turbulence bench to test two competing IFS technologies (lenslet and slicer) for application suitability.

Joanna Barstow, Ingo Waldmann, Giovanna Tinetti, Patrick Irwin

University College London

A070

Building complexity in cloud models for spectral retrieval: observing cloudy planets with the ARIEL mission

The ARIEL mission (Tinetti et al. 2018) will perform a spectroscopic survey of hundreds of transiting exoplanet atmospheres, over a range of spectral resolutions and signal to noise ratios (Barstow et al. 2017a). ARIEL Tier 2 and Tier 3 observations will achieve sufficient spectral resolution and SNR to differentiate between simple cloud parameterisations (e.g. as presented in Barstow et al. 2017b), whereas ARIEL Tier 1 observations will cover around 1000 exoplanets at low SNR and spectral resolving power. This low resolution/photometric survey mode will allow rapid, broad characterisation of planets, providing statistical information on exoplanet atmospheres for the first time and also allowing prioritisation for future, more detailed observations.

Inclusion of clouds is critical for modelling transmission spectra of exoplanets, but this necessarily increases the complexity of the model. More complex models cannot be constrained by low resolution spectra, so a different modelling approach is required for the photometric survey mode spectra from ARIEL compared with the most detailed observations. It may be possible to discriminate between broad cloud types simply using photometric indices, which will be useful for planning follow-up observations, and additionally, if borne out by full retrieval analyses of ARIEL spectroscopic data, will increase the pool of cloudy planets to compare and contrast. Probable extremely cloudy planets may be identified simply from photometric observations; if possible, it would then be preferable to re-observe such planets in secondary eclipse rather than primary transit.

Spectral retrieval techniques (e.g. NEMESIS, Irwin et al. 2008) using parameterised cloudy atmosphere models can constrain the properties of exoplanet atmospheres from transmission spectra. We will present suggested cloud parameterisations of appropriate complexity for the different tiers of ARIEL observation, and discuss these in the broader context of exoplanet cloud modelling. We will also compare the information that can be inferred from synthetic Tier 1 photometric observations with retrieval results from more detailed simulated spectra.

Tinetti et al. submitted Exp Astron;

Barstow et al. 2017a ARIEL Technical Note: Retrievals;

Barstow et al. 2017b, ApJ 834 50;

Irwin et al. 2008, JQSRT 109 1136.

Joanna Barstow, Patrick Irwin, Suzanne Aigrain, Ingo Waldmann

University College London

A071– ORAL PRESENTATION

Pushing the boundaries of transiting exoplanet atmospheres with JWST

The James Webb Space Telescope will provide unprecedented spectral coverage and signal-to-noise ratio for atmospheric observations of transiting exoplanets. As well as enabling more detailed characterisation of Hot Jupiters, with sufficient observational time JWST could constrain atmospheres of terrestrial planets such as those in the TRAPPIST-1 system [1]. Warm sub-Neptunes such as GJ 1214b, that have so far defied detailed analysis due to the obscuring effects of clouds [2], will also become suitable candidates for characterisation.

Increasingly detailed observations will require the development of more sophisticated models. Spectral retrieval techniques have so far been used to good effect in the analysis of transit and eclipse spectra, using relatively simple parameterised atmosphere models [3]. Assumptions and simplifications that are commonly made in retrieval models will no longer be appropriate for the high quality JWST observations, which will present a number of challenges, including: correcting for the presence of unocculted starspots [4]; allowing for the possibility of hemispheric asymmetry in models [5]; and including more complex cloud parameterisations.

I will present synthetic observations of the TRAPPIST-1 planets and GJ 1214b and discuss the possibility of observing such challenging targets with JWST. I will also discuss the necessary improvements to retrieval models of transiting planets in the JWST era, and how these might be achieved.

Barstow, J. K. & Irwin, P. G. J., 2016, MNRASL, 461, 92;

Barstow, J. K. et al., 2017, ApJ, 834, 50;

Kreidberg et al., 2014, Nature, 505, 69;

Rackham, B.; Apai, D.; Giampapa, M., 2017, ApJ, arxiv:1711.05691;

Line, M. R. & Parmentier, V., 2016, ApJ, 820, 7

Daniel Bayliss

University of Warwick

A107

Worlds in Transit – An overview of the TESS and CHEOPS missions

TESS and CHEOPS are two upcoming space missions set to discover and characterise transiting exoplanets by means of high precision photometry. The TESS mission will cover almost the entire sky over two years, with a focus on both bright stars and M-dwarfs. Most stars will be monitored for 27 days with 30 minute cadence, with selected targets having two-minute cadence and targets in field overlap regions being monitored for up to a year. This coverage is set to revolutionise our knowledge of exoplanets, and should deliver the best targets for JWST characterisation. The CHEOPS mission will monitor single stars with high precision in order to better characterise the planetary properties, particularly the planetary radii. There are obvious synergies between these missions. In this talk I will, for each mission, outline the basic properties, provide an update on progress, and highlight opportunities for the UK community by way of public data products and open time calls.

Jayne Birkby

University of Amsterdam

A032

MEASURE: the MMT Exoplanet Atmosphere SURvEy

High-resolution spectroscopy is a robust and powerful tool in exoplanet characterization. It uses changes in the Doppler shift of a planet to disentangle its spectrum from the glare of its host star, and is particularly sensitive to the shape and depth of the planet's individual spectral lines. I will present the first preliminary results from MEASURE: the MMT Exoplanet Atmosphere SURvEy. This 40 night survey of 11 planet atmospheres at R~30,000 is the largest homogenous high-resolution survey to date. I will focus on how the survey will provide an accurate measurement of the temperature at which hot Jupiter atmospheres transition into having thermal inversion layers i.e. stratospheres, and the chemical species and processes responsible for this. After much debate about their existence in the literature, only very recently have we seen strong evidence for stratospheres in hot Jupiters. At high spectral resolution, these features are clearly detected via multiple strong emission lines from e.g. CO, and preliminary results indicate this occurs at hotter temperatures than previously expected. MEASURE not only provides a homogenous dataset to perform comparative exoplanetology, but provides complementary high-resolution spectra for exoplanets observed with HST and Spitzer, allowing the next step in the detailed characterization of exoplanet atmospheres.

Sarah Blumenthal

University of Exeter

A015

Benchmarking of a Long-Chain Carbon Chemistry Network in ATMO

Chemical kinetics has been shown to be important in the investigation of exoplanet atmospheres especially the more temperate. Close-in, highly irradiated planets are driven away from thermochemical equilibrium by non-equilibrium processes driven by transport and photochemistry. Using ATMO, a 1D radiative transfer code that uses the correlated-k method and is coupled to the C0-C2 network of Venot et al. (2012), Drummond et al. (2016) has shown the importance of consistently modelled temperature-pressure profiles on the interpretation of emission spectra. We build upon this work and adopt the same methodology with the implementation of the Venot et al. (2015) chemical network into ATMO. The chemical network from Venot et al. (2015) describes the kinetics of species with up to six carbon atoms (C0-C6 scheme) on a wide range of temperatures (300−2500 K) and pressures (0.01−100 bar). We have chosen this network as it is particularly suitable for the modelling of longer-chain carbon molecules that may be important in the formation of photochemical haze. Sing et al. (2016) points out the importance of modelling clouds and haze in exoplanetary atmospheres and how they may affect observations from the upcoming JWST mission. We present the preliminary results of the implementation of this network and its application to warm to hot exoplanets. We benchmark our results both from the results of Drummond et al. (2016) using the hot planets of HD 189733b and HD 209458b, and over a wider temperature regime (T_{eq} = 500-1500 K) from Venot et al. (2015) for two different metallicity cases.

Amy Bonsor

Institute of Astronomy, University of Cambridge

A016 – ORAL PRESENTATION

White Dwarf Planetary Systems

Planetary systems around white dwarfs provide the only means to probe the composition and geology of exoplanetary systems. Evidence for planetary material in the atmospheres of white dwarfs is crucial. Outer planetary systems can survive to the white dwarf phase, but how does material get from these outer systems onto the white dwarf? Infrared emission close to white dwarfs traces the accretion of dusty material. I will discuss models to explain how dusty material arrives into the atmospheres of white dwarfs, taking into account both detections and non-detections. I will also discuss observations of variability in the infrared emission of polluted white dwarfs and their implications for the dusty accretion of planetary material.

Richard Booth, Katja Poppenhaeger, Chris Watson

Institute of Astronomy, University of Cambridge

A045

From discs to planets: chemical constraints on planet formation

With atmospheric measurements beginning to place constraints on the abundances of the dominant molecular species present in the atmospheres of giant exoplanets, their chemical compositions can provide a link between planets and the environments in which they form. Simultaneously, ALMA is unveiling the physical and chemical evolution of protoplanetary discs, providing direct constraints on the conditions in which planets form. Considering the mutual evolution of discs and composition of planets together can thus provide insight into the processes behind their formation. In particular, I will discuss recent results showing that the processes behind the formation of giant planet cores, such as pebble or planetesimal accretion, leave distinct signatures in their composition. This occurs because pebbles, which contain the largest reservoir of volatiles in the disc, are highly mobile. As the pebbles migrate towards the star they redistribute their volatiles, leaving them in the warmer regions where they sublimate. Giant planets that subsequently build their envelopes in the volatile rich regions of the discs lock in these signatures. In extreme cases, this can result in both the C/O and C/H ratios being super-solar in the planet's atmosphere. Since these signatures cannot be produce in traditional planetesimal accretion scenarios, planets with such a composition would provide smoking gun for pebble accretion. With protoplanetary discs already showing hints of volatile redistribution due to migrating pebbles, the chemical composition of exoplanet atmospheres will soon provide insights into their formation.

Rachel Booth, Katja Poppenhaeger, Chris Watson

Queen's University Belfast

A042 – ORAL PRESENTATION

An improved age-activity relationship and the implications for exoplanets

The magnetic activity emitted by stars is crucial to understanding the potential habitability of exoplanets. The strong radiation (particularly in the X-ray and ultra-violet wavelengths) emitted by a star can cause atmospheric mass loss from the exoplanet. However, over time cool stars spin down due to magnetic braking and the magnetic activity becomes less pronounced. This has led to many studies concerning the evolution of stellar rotation and stellar activity with age. The majority of these studies construct a relationship that is only reliable for ages younger than a gigayear due to the difficulty of determining ages for older stars. However, recent observational advancements have made it possible to study ages for a larger sample of stars through asteroseismology; opening up the possibility of stellar age investigations for stars older than a gigayear. I will present work that has combined ages of stars from asteroseismology and X-ray observations to construct an improved age-activity relationship for cool stars older than a gigayear. When this work is compared to previous studies, it reveals an interesting change in the age-activity relationship that has implications for the long-term habitability of exoplanets orbiting such stars. Additionally, I will present results from recent work concerning the age-activity relationship using emission from the Calcium II H and K lines.

Matteo Brogi

University of Warwick

A081 – ORAL PRESENTATION

Exoplanet atmospheres at high spectral resolution

In recent years, high resolution spectroscopy (R>20,000) with ground-based telescopes has become an invaluable tool to characterise the atmospheres of exoplanets. It has the ability of resolving molecular bands into the individual lines, and of directly detecting the changing radial velocity of close-in planets through cross correlation with template spectra. This technique has produced robust detections of atomic and molecular species in transmission and dayside spectra of transiting and non-transiting hot Jupiters. In addition, it allowed us to measure planet rotation and wind speeds. In this talk I will review the state of the art of the method, current efforts aimed at jointly analysing low- and high-resolution spectra, and a roadmap to extend these measurements to cooler and smaller planets, for instance those found by TESS. I will conclude by showing how, in the era of the E-ELT, this technique will be applicable to search for potential biomarkers in the atmospheres of temperate, rocky planets.

David Brown

University of Warwick

A048 – ORAL PRESENTATION

PLATO - current status and UK contributions

PLATO (PLAnetary Transits and Oscillations of stars) is ESA’s M3 mission. Due for launch in Q4 2026, it will search for terrestrial exoplanets around sun-like stars at orbital distances up to and including the habitable zone. The combination of photometric transit observations and asteroseismology from the spacecraft, with additional, comprehensive follow-up observations, will provide key information (e.g. planetary masses, radii, and bulk densities; orbital periods; stellar irradiance levels; system architectures) needed to characterise the bulk properties and system architectures of hundreds of rocky, icy, and gas giant planets, and to determine the habitability of these diverse new worlds. We provide an overview of the current development status of PLATO, and of the UK's key contributions to this exciting space mission.

Aarynn Carter

University of Exeter

A062 – ORAL PRESENTATION

High Contrast Imaging of Exoplanets and Exoplanetary Systems with JWST

In preparation of the launch of the James Webb Space Telescope (JWST) a broad range of proposals have been selected under the Director’s Discretionary Early Release Science Program (DD-ERS) with the primary goal of rapidly producing representative datasets across the modes of JWST within the first few months of operation. Our accepted program, High

Contrast Imaging of Exoplanets and Exoplanetary Systems with JWST, has been awarded ~52 hours of time and will perform: a) coronagraphic imaging of a newly discovered exoplanet companion, and a well-studied circumstellar debris disk with NIRCam & MIRI; b) spectroscopy of a wide separation planetary mass companion with NIRSPEC & MIRI; and c) deep aperture masking interferometry with NIRISS. These observations have been tailored to the specific goals of our program: 1) generate representative datasets in modes to be commonly used by the exoplanet and disk imaging communities; 2) deliver science enabling products to empower a broad user base to develop successful future investigations; and 3) carry out breakthrough science by characterising exoplanets for the first time over their full spectral range from 2-28 microns, and debris disk spectrophotometry out to 15 microns sampling the 3 micron water ice feature. We present a summary of these observations and our planned science enabling products in order to inform the community ahead of the launch of JWST.

Alex Cridland

Leiden Observatory

A014 – ORAL PRESENTATION

Predicting the Bulk Elemental Abundance of Exoplanetary Atmospheres from Formation Models

The bulk chemical composition of a planetary atmosphere will be dictated by the material from which it accreted. Hence in order to predict the initial chemical state of a planet's atmosphere we need comprehensive models of both chemically evolving protoplanetary disks, as well as planet formation. Here I will present such a theoretical framework.

My work combines an evolving photochemical model of the gas in protoplanetary disks with planet formation in the planetesimal accretion paradigm to predict the incoming molecular abundance of the gas that forms a Jupiter-massed planet's earliest atmosphere. This model includes the effect of dynamical planet trapping, which limits the rate of Type-I migration, and places limits on the possible locations where gas accretion happens.

Due to gas accretion alone, I find that the planetary carbon-to-oxygen ratio (C/O) matches the stellar C/O exactly. This result is driven by our assumption that accreting planets are found at planet traps, and the fact that planet traps tend to converge as the disk ages. I will discuss what role the accretion of icy planetesimals can play in deviating the planetary C/O away from the stellar value. I similarly find that the planetary carbon-to-nitrogen ratio (C/N) does not deviate from the stellar value, and will discuss what role the JWST will play in testing this prediction.

Mario Damiano

University College London

A041

Near-IR transmission spectrum of HAT-P-32 b using HST / WFC3

Thousands of exoplanets have been discovered with a huge range of masses, sizes and orbits. The next step to characterize them is to study their atmosphere. The atmospheres of giant planets are mostly made of hydrogen and helium. The relevant questions therefore

concern the amounts of all elements other than hydrogen and helium, i.e. the heavy elements, that are present. The atmospheres of hot Jupiters present a critical advantage compared to the planets of the Solar System: their high temperature.

Unlike Jupiter and Saturn, there is no cold trap in their atmosphere for species such as H_2O, CH_4, NH_3, CO_2 etc., which condense at much colder temperatures. Observations of hot gaseous exoplanets can therefore provide a unique access to their elementary composition (especially C, O, N, S) and enable the understanding of the early stage of planetary and atmospheric formation during the nebular phase and the following few millions years.

In this context Hubble Space Telescope has been a key instrument to start achieving some common behaviour among Hot Jupiters. Here I present new spectroscopic observations of hot-Jupiters' atmospheres obtained with the WFC3 camera. In this poster I will focus on the data reduction method used, on two technique used for the data analysis (parametric pipeline and ICA) and on the interpretation of the results through state of the art spectral retrieval models.

Guy Davies
University of Birmingham

A074 – ORAL PRESENTATION

Population Studies and Exoplanets

The traditional way to study exoplanets is to consider the planet, the system, or the star. But in this new era of abundant exoplanets, there is much to be learnt from the ensemble. We propose this session on Population Studies and Exoplanets as a way to summarise the ongoing work in exoplanet population studies but also to draw from expertise in other fields.

We aim to provide an interesting and informative session that draws on existing population study experience. We propose a keynote speaker with extensive experience in population studies but in an adjacent field (i.e., galactic archaeology) where techniques and tools are somewhat more established. We hope to generate interest by providing a pedagogical session themed around ensembles and populations and to highlight the exciting work that is currently ongoing in exoplanet population studies.

Laetitia Delrez
University of Cambridge (Cavendish Laboratory)

A100 – ORAL PRESENTATION

Follow-up of the TRAPPIST-1 system with Spitzer

The recently detected TRAPPIST-1 planetary system, with its seven planets transiting a nearby ultracool dwarf star, offers the unique opportunity to perform comparative exoplanetology of temperate Earth-sized worlds. To further advance our understanding of these planets' compositions, energy budgets, and dynamics, we are conducting an intensive photometric monitoring campaign of the system using both ground-based and space-based facilities. Most notably, we have now more than tripled the number of transit events observed with the Spitzer Space Telescope on TRAPPIST-1 with respect to what has been presented in the discovery paper. In this talk, I will describe our observing campaign and its current

results. I will discuss how these results improve our understanding of the TRAPPIST-1 system and help prepare the detailed atmospheric characterization of its planets with the upcoming James Webb Space Telescope.

Rupert Dodkins

University of Oxford

A039

A Simulator for Exoplanet Direct Imaging with MKIDs

Microwave Kinetic Inductance Detectors have the potential to directly image terrestrial exoplanets with a ground-based telescope. To achieve the parent-planet contrast ratios and separations, necessary for small mass terrestrial planets, requires fast (ideally photon counting), large format arrays (tens of kilopixels) and low noise (sub-electron read noise and dark current) detectors. These properties, both improve the level of speckle noise suppression through conventional methods, and enable new techniques of speckle suppression that remain effective at small inner working angles. We present a tool that implements these techniques and demonstrates the performance of an MKID-based system over conventional semiconductor-based systems.

Benjamin Drummond

University of Exeter

A046 – ORAL PRESENTATION

Observable signatures of wind-driven chemistry with a fully consistent 3D radiative hydrodynamics model of HD 209458b

I will present a study of the effect of wind-driven advection on the chemical composition of hot Jupiter atmospheres using a fully-consistent 3D hydrodynamics, chemistry and radiative transfer code, the Met Office Unified Model (UM). Chemical modelling of exoplanet atmospheres has primarily been restricted to 1D models that cannot account for 3D dynamical processes. We have coupled a chemical relaxation scheme to the UM to account for the chemical interconversion of methane and carbon monoxide. This is done consistently with the radiative transfer meaning that departures from chemical equilibrium are included in the heating rates (and emission) and hence complete the feedback between the dynamics, thermal structure and chemical composition. We simulate the well-studied atmosphere of HD~209458b. We find that the combined effect of horizontal and vertical advection leads to an increase in the methane abundance by several orders of magnitude; directly opposite to the end found in previous works. Our results demonstrate the need to include 3D effects when considering the chemistry of hot Jupiter atmospheres. We calculate transmission and emission spectra, as well as the emission phase curve, from our simulations. We conclude that gas-phase non-equilibrium chemistry is unlikely to explain the model--observation discrepancy in the 4.5 micron Spitzer/IRAC channel. However, we highlight other spectral regions, observable with the James Webb Space Telescope, where signatures of wind-driven chemistry are more prominent.

Billy Edwards

University College London

A101

Twinkle: A mission to unravel the story of planets in our galaxy

Twinkle is a small space telescope conceived to observe spectroscopically hundreds of extrasolar planets over a broad wavelength range. Twinkle will be able to reveal the chemical composition, weather and history of worlds orbiting distant stars.

Twinkle's highly-stable instrument will allow the photometric and spectroscopic observation of a wide range of planetary classes around different types of stars, with a focus on bright sources close to the ecliptic. The planets will be observed through transit and eclipse photometry and spectroscopy, as well as phase curves, eclipse mapping and multiple narrow-band time-series. The targets observed by Twinkle will be composed of known exoplanets, mainly discovered by existing and upcoming ground surveys in our galaxy (e.g. WASP, NGTS and radial velocity surveys), and will also feature planets newly-discovered by space observatories (Cheops, TESS). Twinkle will be capable of simultaneously studying targets from the optical to IR (0.4-4.5 micron).

Additionally, the high stability and sensitivity of its instrumentation mean Twinkle could be utilised for observing a multitude of other targets. I will present the current work being done to explore Twinkle's capabilities to observe exoplanets, Solar System objects and other potential targets such as bright stars, brown dwarfs, disks and supernovae.

Tom Evans

University of Exeter

A033

Atmospheric characterisation of the hot Jupiter WASP-121b

WASP-121b is one of the standout planets available for atmospheric characterisation, both in transmission and emission, due to its large radius (~2 Jupiter radii) and high temperature (~2700 Kelvin). Recently, our group measured the planet's near-infrared thermal spectrum with Hubble, revealing the 1.4 micron water bandhead in emission. This was the first time a resolved spectral feature had been observed in emission for an exoplanet, and implies the dayside hemisphere has a strong thermal inversion. Such inversions have long been postulated for the most highly-irradiated hot Jupiters, with gas-phase TiO and VO potentially absorbing a significant fraction of incoming optical radiation. However, it has also been argued that TiO/VO may be depleted from the upper atmosphere by vertical and/or day-night cold-trapping. Thus, the extent to which thermal inversions form, and the cause of such inversions, remain major outstanding questions. WASP-121b is one of the most promising targets available for addressing these fundamental issues and will soon become one of the best-studied of all the known exoplanets. In this talk, I will describe our results to date, as well as the upcoming observations we have planned to reveal the nature of this benchmark atmosphere.

Benjamin Fernando

University of Oxford

A029

Asteroseismology with TESS: a new method for predicting stellar oscillation frequencies

The upcoming launch of the Transiting Exoplanet Survey Satellite (TESS) will produce a wealth of new data not only for exoplanet detection, but also for asteroseismology. Asteroseismic analysis can yield insight into the structure, evolution and dynamics of other stars, and is useful in understanding their periodic, intrinsic oscillations which must be accounted for when hunting for exoplanets. In the last few years, codes such as MESA-GYRE have been developed for forward modelling of these oscillation spectra, however there is still room for development.

AxiSEM3D is a highly efficient, parallelised terrestrial seismology code which is currently being adapted for solar and stellar use.It should offer the opportunity for fast, accurate computation of stellar mode spectra - including for stars on which spherical harmonic based normal mode analysis breaks down, such as those which are highly oblate.

This poster will present the methodology behind AxiSEM3D and discuss the physical effects which we currently plan to incorporate. Once implemented, calculation of modes should be possible with only a radial seismic profile as input.

Christian Fischer

University of Cologne

A002

Star-planet interaction in the TRAPPIST-1 system

We investigate the TRAPPIST-1 system with its seven close-in terrestrial planets for possible electromagnetic star-planet-interactions. Our results show that the innermost planets, especially TRAPPIST-1b and c, are subject to sub-Alfvénic interaction. Both planets are therefore expected to generate Alfvén wings, which can couple to the star. Our model describes the stellar wind in a semi-analytic approach as a thermally driven wind, according to the Parker-model. We perform a systematic parameter study to estimate the Alfvén Mach number at each planet and the possibly resulting Poynting fluxes. That allows for conclusions about the type of electromagnetic interaction.

Clémence Fontanive

Institute of Astronomy, University of Edinburgh

A063

Brown Dwarf Binary Properties as a Function of Age

The binary properties of brown dwarfs in the field form a continuum with the trends observed in the stellar regime, with fewer binary systems, smaller separations and higher mass ratios seen around lower-mass objects. However, young brown dwarfs appear to have different multiplicity properties than those observed in the older field population. Measuring and understanding these discrepancies is necessary to allow more realistic modelling for formation theories and be able to predict the evolution and fate of binaries. In this talk, I will present results from an HST campaign compiled to investigate and constrain the binary statistics for the extreme low-mass end of the Initial Mass Function as a function of age. Based on a Bayesian statistical analysis of companion population distributions, I will discuss the implications of observed disparities in substellar binary properties with age for formation and evolution models.

Duncan Forgan

University of st Andrews

A061

Automatic Identification of Spiral Structure in Hydrodynamic Simulations of Discs

I will demonstrate numerical techniques for automatic identification of individual spiral arms in hydrodynamic simulations of astrophysical discs. Building on our earlier work, which used tensor classification to identify regions that were “spiral-like”, we can now obtain fits to spirals for individual arm elements.

Our methods not only permit the estimation of pitch angles, but also direct measurements of the spiral arm width and pattern speed, as well as the properties of gas in the arm and in interarm regions. Our techniques will allow the tracking of material as it passes through an arm. We will display results using smoothed particle hydrodynamics simulations, but we stress that the method is suitable for any finite-element hydrodynamics system. We anticipate our techniques will be essential to attempts to determine the origin of recently observed spiral structures in protostellar discs, as well as the larger process of star formation in disc galaxies.

Siddharth Gandhi

Institute of Astronomy, Cambridge

A008

HyDRA: A New Paradigm for Atmospheric Retrieval of Exoplanets

Thermal emission spectra of exoplanets provide constraints on the chemical compositions, pressure-temperature (P-T) profiles, and energy transport in exoplanetary atmospheres. Accurate inferences of these properties rely on the robustness of the atmospheric retrieval methods. While retrieval codes have provided significant constraints on molecular abundances and temperature profiles in several exoplanetary atmospheres, the constraints on their deviations from thermal and chemical equilibria have yet to be fully explored. HyDRA, our new disequilibrium retrieval framework, is a step in this direction. For a given dataset, the retrieved chemical compositions and P-T profiles are used in tandem with our self-consistent atmospheric model to constrain layer-by-layer deviations from chemical and radiative-convective equilibrium in the observable atmosphere. We demonstrate this on the Hot Jupiter WASP-43b with a high-precision emission spectrum. We retrieve a water vapour mixing ratio that is solar, in agreement with previous studies. With our disequilibrium analysis we find that the dayside P-T profile is consistent with radiative-convective equilibrium and that the derived compositions are also consistent with thermochemical equilibrium. In the era of high precision and high resolution emission spectroscopy, HyDRA provides a path to retrieve disequilibrium phenomena in exoplanetary atmospheres.

Nikolaos Georgakarakos

New York University Abu Dhabi

A086

Are giant planets bad neighbours for habitable worlds?

The presence of giant planets influences potentially habitable worlds in various ways. Massive celestial neighbours can facilitate the formation of planetary cores and modify the influx of asteroids and comets towards Earth-analogs later on. Furthermore, giant planets can indirectly change the climate of terrestrial worlds by gravitationally altering their orbits. In this work we present a method for quantifying how the gravitational perturbations of a giant planet can affect the capacity of a potentially habitable world to have liquid water on its surface. Investigating a number of well characterized exoplanetary systems known to date to host a main sequence star and a giant planet, we show that the presence of ’giant neighbours’ can reduce a terrestrial planet’s chances to remain habitable, even if both planets have stable orbits. In providing constraints on where giant planets cease to affect the habitable zone size in a detrimental fashion, we identify prime targets in the search for habitable worlds.

Samuel Gill

University of Keele

A060

How well can we measure the mass and radius of low-mass eclipsing binaries with the transit method?

One of the most popular methods of measuring the radius of of an exoplanet (or eclipsing star) is with the transit method. This can be combined with radial velocity measurements and evolutionary models to measure the mass of the eclipsed star. Ground based observations can achieve precision of a few percent while current (and future generations of) space missions can achieve precision's of 0.1% for both mass and radius of host stars. We discuss more subtle effects which are popularly ignored from uncertainty calculations: choice of limb-darkening law, third-light, stellar activity, He-enhancement, Alpha-enhancement, choice of mixing-length parameter and many more. Incorrectly accounting for these effects can introduce uncertainties approaching 5% for both mass and radius. Further to this, the astrophysics community presents inhomogeneous measurement styles which, when combined with the above, can skew exoplanet statistics and provide unreliable tests or stellar models. We present a discussion of how these arise and what may be done to mitigate this problem.

Maximilian Guenther
University of Cambridge

A004 – ORAL PRESENTATION

Unmasking hidden systems with NGTS

The Next Generation Transit Survey (NGTS) has been hunting for exoplanets from Paranal since 2016. Thereby, its ability to identify false positives is crucial. Background eclipsing binaries (BEBs) blended in the photometric aperture can mimic shallow exoplanet transits and are costly in follow-up time. Moreover, constant blends can lead to underestimation of planet radii. In this talk, I will highlight our ability to detect flux-centroid shifts with a precision down to 0.25 milli-pixel, capable of identifying 80% of BEBs. Further, I will introduce 'blendfitter', a novel Bayesian tool box to conjointly model photometry, centroids, radial velocity cross-correlation functions and their bisectors. I will demonstrate how we employed this method to disentangle an unresolved system which would otherwise have been erroneously disregarded. These achievements make NGTS the first ground-based wide-field transit survey ever to successfully apply these techniques, enabling the production of a robust planet candidate list.

Cassandra Hall
University of Leicester

A096

Is the spiral morphology of the Elias 2-27 circumstellar disc due to gravitational instability?

A recent ALMA observation of the Elias 2-27 system revealed a two-armed structure extending out to ~300 au in radius. The protostellar disc surrounding the central star is unusually massive, raising the possibility that the system is gravitationally unstable. Recent work has shown that the observed morphology of the system can be explained by disc self-gravity, so we examine the physical properties of the disc necessary to detect self-gravitating spiral waves. Using three-dimensional Smoothed Particle Hydrodynamics, coupled with radiative transfer and synthetic ALMA imaging, we find that observable spiral structure can only be explained by self-gravity if the disc has a low opacity (and therefore efficient cooling), and is minimally supported by external irradiation. This corresponds to a very narrow region of parameter space, suggesting that, although it is possible for the spiral structure to be due to disc self-gravity, other explanations, such as an external perturbation, may be preferred.

Richard Hall

University of Cambridge

A102

Demonstrating the Feasibility of Intense Radial Velocity Surveys for Earth-twin Discoveries

The detection of an Earth-mass planet in the habitable zone of a solar type star will be a ground-breaking discovery. Current instruments are just shy of the precision needed to make these detections, and we are still confounded by the quasi-periodic stellar signals. The HARPS3 instrument is designed to have the measurement precision required to make this discovery, and the Terra Hunting Experiment will have a unique and intense observation schedule to help combat the stellar signals.

I present an end to end simulation of HARPS3 radial velocity data and use a multi-nested Bayesian analysis package to find the planetary candidates within the data. We factor in the full 3D Keplerian system architecture, realistic simulated stellar noise, a proposed observation schedule, and location specific weather patterns for our entire 10 year survey. I will discuss our promising results in the context of detecting long period earth planets and compare them to simulated results of a typical radial velocity survey. We also include the results of a continuous data series, representing the space-observatory case.

Mark Hammond

University of Oxford

A104 – ORAL PRESENTATION

Climates of Lava Planets

Lava planets such as 55 Cancri e may have atmospheres with extreme atmospheric dynamics driven by their day-night forcing contrast. Their climates may also be affected by condensables and clouds.

I will talk about our work modelling the climates of lava planets, driven by observations of 55 Cancri e which suggested an atmosphere with a puzzling temperature distribution. I will discuss our work modelling this planet with an idealised numerical circulation model, and show how we put constraints on a possible atmospheric composition and thickness.

I will then talk about our follow-up work using a more sophisticated GCM with real-gas radiation and cloud formation and transport, and how these processes may be crucial to understanding lava planet climates and our observations of them.

Tom Hands

University of Zürich

A024

Mass transfer and dynamical evolution of debris discs in the stellar birth environment

We perform high-N, direct summation N-body simulations of the early phases of open cluster evolution. The stars in our clusters host populations of test particles arranged in Kuiper-belt style planetesimal discs. We evolve the clusters and debris discs simultaneously in one simulation, such that the exact cluster potential is known at each time-step, and no approximations are required to detemine the effect the cluster environment has on the planetesimals. We show that the early stages of evolution for Hyades-style clusters readily lead to the transfer of planetesimals between stars, free-floating planetesimals (such as A/2017 U1), and dynamically excited planetesimal discs. We also show that planetesimals captured from the stellar birth environment are not necessarily dynamically distinct from those native to a star. We discuss the implications of our results for both our own solar system and exoplanetary systems.

John Harrison

Institute of Astronomy, Cambridge

A049

Polluted White Dwarfs: Constraints on the Origin and Geology of Exoplanetary Material

White dwarfs that have accreted rocky planetary bodies provide unique insights regarding the bulk composition of exoplanetary material. The frequency of solar system-like chemistry and geology in the galaxy is poorly understood. In our work we use the observed pollutant chemical abundances to constrain where in the planetary system the pollutant bodies originated and their geological and collisional history. We find that at least 2, but possibly up to 8, of the 17 systems analysed in our work have accreted a body dominated by either a core-like or a mantle-like material. These bodies are expected to be fragments formed in collisions between larger bodies that have differentiated into a core and a mantle, providing evidence for differentiation in exosystems. The even spread in the core mass fraction of the pollutants, and the lack of crust-rich pollutants in the 17 systems studied here agree with such a collisional model. The compositions of many pollutants exhibit trends related to elemental volatility, which we link to the temperatures and, thus, the locations at which these bodies formed. Our analysis shows that the abundances observed in 13 of the 17 systems considered are consistent with the compositions of nearby stars in combination with a trend related to volatility. The even spread and large range in the predicted formation location of the pollutants suggests that pollutants arrive in white dwarf atmospheres with a roughly equal efficiency from a wide range of radial locations, from very close to the host star, where refractory species dominate, to outside of the nitrogen ice line, where many ice species are abundant.

Éric Hébrard
University of Exeter

A028 – ORAL PRESENTATION

A pale orange dot around an active young Sun : prebiotic chemistry and habitability of early Earth

Understanding how early Earth may have provided the perfect conditions for producing and preserving complex biological molecules, the building blocks of life, represents one of the greatest unsolved questions. But past research aiming to assess the prebiotic potential and habitability of our planet over time has largely ignored the vastly different conditions that have existed in our planet's long habitable history. I will present how these two facets of the same problem can be reconciled if we look at the early Earth orbiting its young Sun 3.8-2.5 billion years ago as a habitable yet dramatically different environment than we know it today.

First, using magnetohydrodynamic simulations constrained by Kepler Space Telescope observations, we have proposed that energetic particles accelerated in shock waves driven by frequent and powerful coronal mass ejection events – so-called superflares - from the young Sun could penetrate into a weakly reducing atmosphere, initiate the reactive chemistry by breaking molecular nitrogen N_2, carbon dioxide CO_2, and methane CH_4, and eventually produce nitrous oxide N_2O, a potent greenhouse gas, and hydrogen cyanide HCN, an essential prebiotic compound. Secondly, geochemical evidence suggests early Earth was intermittently enshrouded in a Titan-like, organic-rich haze resulting from photochemistry that may also have provided an additional large-scale source of activated prebiotic material. Using coupled climate-photochemical-microphysical simulations, we have demonstrated that a relatively thick haze layer could help maintain habitable conditions with liquid surface water, even with the fainter young Sun. We have found that an optically thicker haze is self-limiting due to its self-shielding properties, preventing catastrophic cooling of the planet. We have also found that haze may even enhance planetary habitability through UV shielding, reducing surface UV flux by about 97% compared to a haze-free planet, and potentially allowing survival of land-based organisms 2.7-2.6 billion years ago.

Our overall concept provides insight into how life may have initiated on Earth and how to search for the spectral signatures on planets "pregnant" with the potential for life.

Christina Hedges
Bay Area Environmental Research Institute, NASA

A084 – ORAL PRESENTATION

Kepler/K2 Mission Status and Legacy Dataset Overview

The K2 project has expanded the legacy of the Kepler mission by using the repurposed spacecraft to observe short-period planets around a more diverse population of stars. While fuel is running low, Kepler/K2 science is only getting started. At time of writing, K2 has completed 16 campaigns, and will shortly deliver the 17th. We anticipate only 20% of the K2 planet sample has been published, based on Kepler results. We have observed a wide range of science targets, including young stars, clusters, galaxies and supernovae. In this talk I will review the star and planet population across all K2 campaigns, highlighting several unexplored uses of the public data. With fuel expected to run out this year, I will discuss the

closing Campaigns and explain the data archive and bespoke software tools the K2 mission intends to leave behind for posterity.

Alex Hindle

Newcastle University

A022

Consequences of shallow water magnetohydrodynamic waves on hot Jupiters

We discuss how interactions between magnetically modified planetary-scale waves and mean zonal flows can generate large variations in the equatorial circulation patterns of hot Jupiters. We highlight how an azimuthal background magnetic field changes the nature of the modes present in the inviscid, incompressible shallow water magnetohydrodynamic (SWMHD) system and propose how the magnetic modification of the planetary-scale waves can disrupt the hydrodynamic mechanism believed to cause equatorial superrotating jets. We discuss the consequences of this proposed mechanism and its implications on providing a constraint for the magnetic field strength of hot Jupiters, such as HAT-P-7 b and CoRoT-2b, that exhibit westward peak brightness offset.

Sasha Hinkley

University of Exeter

A095 – ORAL PRESENTATION

Directly Imaging Planets with METIS on the ELT

I will give an overview of the potentially transformative capabilities for directly imaging Extrasolar Planets using the Mid-infrared ELT Imager and Spectrograph (METIS), one of the first-light instruments on the upcoming European Extremely Large Telescope (ELT). METIS will be sensitive to wavelengths as long as 17 microns, and will be the only first light instrument on the next generation of extremely large telescopes operating in the thermal infrared. My talk will demonstrate how this wavelength range will be particularly powerful for the atmospheric characterization of extrasolar planets, allowing both observers and theorists to discriminate between varying chemical abundances in the atmosphere, not possible using near-infrared alone. In addition, the 39-metre aperture of the Extremely Large Telescope will allow resolution on scales of comparable to the ice-line at 2-3 AU where massive, Jovian exoplanets are expected to form. Importantly, these zones of planet formation will be out of reach to the other extremely large telescopes such as GMT and TMT. Lastly, I will demonstrate how METIS operating at 10 microns will be sensitive enough to directly image earth-sized planets orbiting the nearest stars. METIS will also be equipped with spectrographs in this wavelength region providing direct abundance measurements of the presence of organic molecules such as CH_4, CO_2, H_2O and O_3 in the atmospheres of the nearest Earth-sized planets. If time allows, I will demonstrate how upcoming observations with JWST, including our recently accepted Early Release Science Program, will be essential to planning for the most efficient observations with METIS.

Vedad Hodzic

University of Birmingham

A043

amelie: Tool for fitting photometry and radial velocities of transiting planets and eclipsing binary systems

We present a flexible code for light curve and radial velocity fitting that can be applied to transiting planets and eclipsing binary systems alike. **amelie** performs a separate or joint fit on multi-band data with simultaneous detrending. The code uses **ellc** to generate model light curves and radial velocity curves, and the **emcee** package to obtain the posterior distribution of the parameters using a Markov chain Monte Carlo algorithm. **amelie** is currently being applied to the analysis of various eclipsing systems, with papers being prepared for publication. In the future, the code will be extended to include Rossiter-McLaughlin analysis, and likely circumbinary planets.

Mark Hollands

University of Warwick

A018

Chemistry and evolution of white dwarf planetary systems

All known main-sequence exoplanet hosts will eventually evolve into white dwarfs, with much of their planetary systems surviving. Reduced dynamical stability can scatter small bodies such asteroids or minor planets, occasionally leading to the accretion of planetary material onto the central white dwarf, temporarily enriching the stellar atmosphere with metals. Spectral analysis can therefore be used to infer the composition of the accreted parent body. In our work we have performed a spectroscopic analysis of 230 cool (Teff < 9000K, t_cool > 1Gyr) white dwarfs in SDSS, using only their optical spectra. Due to the size of our sample, we have inferred a wide range of planetary compositions, from bodies enhanced in Ca and Ti indicating crust-like material, to those dominated by Fe and Ni indicating the accretion of planetary cores. Finally, we investigate the sample in terms of their white dwarf cooling ages, and find the very oldest systems accrete smaller amounts of material. From this we infer that the reservoir of material available for scattering is typically depleted on a ~1Gyr timescale.

Matthew Hooton

Queen's University Belfast

A001

Excursions into inversions: first results from the QUB i- and z-band secondary eclipse campaign

Detecting and measuring thermal emission from exoplanets immediately before and after occultation by their host stars is an important tool for studying exoplanet atmospheres. Taking this measurement over a range of wavelengths allows an emission spectrum to be built up, which alludes to atmospheric features including chemical composition, thermal structure and circulation efficiency. Secondary eclipse observations to date have largely been at wavelengths red-ward of 1 μm, in no small part due to the fact that most targets are insufficiently large or hot to have detectable secondary eclipse signals at shorter wavelengths with current instrumentation. Observations of secondary eclipses in the i- and z-bands are of particular interest as this window contains prominent TiO and VO features (compounds thought to give rise to temperature inversions in the hottest exoplanets) and is a good discriminator between models for carbon-rich and carbon-poor planets. There have also been notable discrepancies in the reported secondary eclipse depths in this window, possibly due to variability of planetary thermal emission properties as a result of storms. I will present the results of the QUB secondary eclipse campaign for ultra-hot Jupiters WASP-12b, WASP-103b and KELT-16b, including one of the first robust secondary eclipse detections in the i-band.

Jack Humphries

University of Leicester

A069

Changes in the metallicity of gas giant planets due to pebble accretion

We run numerical simulations to study the accretion of gas and dust grains onto gas giant planets embedded into massive protoplanetary discs. The outcome is found to depend on the disc cooling rate, planet mass, grain size and irradiative feedback from the planet. If radiative cooling is efficient, planets accrete both gas and pebbles rapidly, open a gap and usually become massive brown dwarfs. In the inefficient cooling case, gas is too hot to accrete onto the planet but pebble accretion continues and the planets migrate inward rapidly. Radiative feedback from the planet tends to suppress gas accretion. Our simulations predict that metal enrichment of planets by dust grain accretion inversely correlates with the final planet mass, in accordance with the observed trend in the inferred bulk composition of Solar System and exosolar giant planets.

To account for observations, however, as much as ~30-50% of the dust mass should be in the form of large grains.

John Ilee

Institute of Astronomy, University of Cambridge

A044

Chemical evolution of the youngest planet forming discs

Protoplanetary discs are one of the most extreme environments in astrophysics, spanning a huge range of temperatures and densities. As such, modelling their chemical evolution is challenging, and has often been reduced to the study of 2-dimensional, axisymmetric discs. However, the advent of ALMA has shown that many protoplanetary discs do not conform to this axisymmetry. In particular, the influence of the dynamic evolution of the disc on the chemical evolution has not been well studied.

I will discuss my work on the calculation of disc chemistry in three dimensions, including the effects of self gravitating shocks in young, massive discs and their implications for the initial chemical conditions of more evolved, Class II protoplanetary discs. I will present the application of these techniques to planet formation itself, outlining my recent work to

characterise the chemical composition of protoplanetary fragments formed via gravitational instability, finding that simple assumptions about their composition may not hold.

Finally, I will discuss ongoing work assessing the effects of dynamics on the abundance of complex organic molecules (including those that are biologically-relevant) in discs and protoplanets, and predictions for the observability of these objects with facilities such as ALMA and the SKA.

James Jackman

University of Warwick

A079

Detecting and characterising stellar flares with NGTS

The Next Generation Transit Survey (NGTS) is a wide-field survey designed to observe bright (I<16) K and M stars, in the search for transiting Neptune-sized exoplanets. Along with this, NGTS is capable of detecting a range of astrophysical phenomena, in particular stellar flares. NGTS operates with an exposure time of 10 seconds (13 second cadence), meaning that for all stars it is able to obtain a better temporal resolution than the Kepler short cadence and even the upcoming TESS mission.

We have searched NGTS fields for stellar flares, so far identifying hundreds of flaring events across a range of spectral types. This includes the detection of high amplitude “superflares”, with energies hundreds of times the Carrington event, from G, K and M type stars. These events can subject orbiting planets to intense XUV irradiation and flux of charged particles, which can act to erode planetary atmospheres and possibly cause biological damage to surface organisms. With our data we have been able to investigate the energies and rates of such events, aiding our understanding of the habitability of these systems and probing the underlying statistics of flaring systems. As well as this we can focus on single flares of interest, such as the first ground-based CCD detection of G star superflares. In this talk we will present the current results from our search, along with future plans for characterising stellar flares with NGTS.

Baz Jackson

School of Biosciences, University of Birmingham

A056 – WITHDRAWN FROM POSTER PRESENTATION

Hydrothermal vents and pH gradients at the origin of life on earth and on other planets?

It is widely understood that energy sources in the environment were used to drive early metabolism and polymerisation reactions at the origin of life on earth. The chemical nature of these energy-transduction reactions is unknown and therefore open to speculation. In numerous (>50) publications, Drs MJ Russell, W Martin , N Lane and their colleagues during the last 25 years have promoted the hypothesis that the energy of a “natural” pH gradient (Δ pH, of some 4 units) between a relatively acidic primeval ocean and a relatively alkaline solution issuing from hydrothermal vents provided energy to power primitive, inorganic molecular machines embedded in interposed inorganic membranes to drive, for example, either simple redox reactions or the synthesis of pyrophosphate. This “natural pH gradient hypothesis" has drawn inspiration from the fact that extant living organisms on earth derive most of their energy using "chemiosmotic coupling" mechanisms, in which proteins "pump" protons (H3O+) across thin lipid membranes to generate a proton (electrochemical) gradient. Protons are then driven back across the membrane by the gradient through protein molecular machines, thus using the energy of Δ pH, for ATP.

Simple and attractive though the natural pH gradient hypothesis might appear, and though it has been widely cited, we shall here consider that it is highly unlikely to have played a role in the origin of life on Earth and, by implication, of equivalent life on other planets.

Firstly, a requirement of the hypothesis is that to make effective use of the natural Δ pH the inorganic membranes interposed between acidic ocean and alkaline vent must have been thin (a few nanometres) relative to the size of the inorganic molecular machines. That is to say, it would have been necessary to focus the Δ pH across the membrane and its machines (Jackson JB, 2016, J Mol Evol, doi:10.1007/s00239-016-9756-6). To date, only thick inorganic membranes (>1µm) have been synthesised in the laboratory under plausible prebiotic conditions, and such membranes would have been inappropriate for effective operation in a natural pH gradient mechanism.

Secondly, we might suppose that the simplest interposed ancient inorganic membranes could have been planar structures that were stretched across orifices in the rocks lying between ocean and vent. However, under the influence of hydrodynamic pressure changes in the ocean and vent, such delicate membranes would have been highly unstable, and quite unsuitable for hosting functional molecular machines at the dawn of life. Inorganic bubbles, vesicles, networks of interconnected compartments and micropores have therefore been alternatively suggested to comprise the putative membranes separating ocean water from vent fluid – summarised in Jackson JB, 2017, Life, doi: 10.3390/life7030036. However, some of these elaborate, theoretical structures would have afforded only stepped, and thus very small, fractions of the overall Δ pH to insignificant levels, thus lowering the available ΔG across individual membranes. In the 25-year lifetime of the natural pH gradient hypothesis, no experimental verification has been presented to illustrate the stable transection of membranes in such structures by a large pH gradient connected to fluid reservoirs equivalent to those of the oceans and vents.

Thirdly, we should recognise that a molecular machine utilising energy of a Δ pH must be mechanistically complex; it must "couple" the flow of protons across the membrane to its associated chemical reaction. We have only a limited understanding of how even well-characterised modern-day protein molecular machines achieve this difficult task. In prebiotic periods before emergence of life we have to imagine how relatively simple inorganic constituents could have assembled by chance on a relevant timescale into a population of complex molecular machines capable of binding reactants and products, and coupling the reaction chemistry of proton. Flow. We must consider how these molecular machines could have been integrated with an appropriate orientation into the putative, thin inorganic membranes effectively to use the energy of the Δ pH.

Proponents of the RNA world hypothesis have often been challenged to show experimentally how purine and pyrimidine nucleotides (and amino acids) might have been synthesised in plausible pre-biotic conditions. Their experiments have met with encouraging success. Equivalently, we must expect supporters of the natural Δ pH gradient hypothesis (and other hypotheses) to provide experimental data. However, thus far, no inorganic molecular machine capable of utilising a Δ pH has ever been constructed in the laboratory. The claim of Δ pH-driven reduction of carbon dioxide to formate and formaldehyde in an inorganic "origin of life reactor" (Herschey B et al, with Labe N, 2014, J Mol Evol, doi: 10.1007/s00239-

014-9658-4) was fundamentally flawed by the authors' misunderstanding of chemical equilibria (Jackson JB, 2017, J Mol Biol, doi: 10.1007/s00239-017-9805-9).

We should not be seduced by the apparent simplicity of the natural pH gradient hypothesis into thinking that the origin of other forms in the universe (on exoplanets) might have easily and commonly involved natural pH gradients. Modern molecular machines capable of utilising Δ pH in living organisms on earth probably only emerged after the evolutionary arrival of proteins- that is, rather late in the development of life.

Marija Jankovic

Imperial College London

A057

Dust enhancement in the inner disk due to the MRI

The formation pathway of the abundant close-in super-Earths and mini-Neptunes is still unclear. Do they form *in situ* or migrate inwards as embryos? If the former, then the key step to planet formation is dust enrichment of the inner protoplanetary disk. Dust is subject to growth by coagulation, and radial drift and fragmentation due to gas drag and turbulence. In the outer disk the dust particles are expected to quickly grow and drift inwards. The inner disk structure, governed by viscous accretion due to the magneto-rotational instability (MRI), features a local gas pressure maximum that could potentially trap the drifting dust particles.

We examine the evolution of dust radial distribution and dust particle size in a steady-state gaseous disk, with the inner disk gas structure self-consistently determined from MRI criteria (Mohanty et al. 2017).

We find that in the inner disk turbulent fragmentation limits the size of dust particles, which thus remain too small to feel significant gas drag and therefore do *not* accumulate at the local gas pressure maximum. However, as a decrease in particle size also implies less radial drift, this ultimately leads to *dust enhancement throughout the inner disk*, interior to the pressure maximum.

Luke Jonathan Johnson, Charlotte M. Norris*

Imperial College London

A054

Simulations of Stellar Variability

The radiative output of stars is not constant, with brightness fluctuations observed as they rotate due to magnetic surface features such as cool starspots and hot active regions. To facilitate analysis of this phenomenon, we present ACTReSS, a software tool for calculating the incident flux from a model active stellar surface as it varies throughout a rotation. The model uses a non-linear limb-darkening law with coefficients derived from MURaM 3D magneto-convection simulations for the quiet Sun and bright active regions. This allows us to investigate the dependence of the flux variation on spectral type and wavelength.

*in collaboration with Yvonne C. Unruh (Imperial College); Sami K. Solanki, Natalie A. Krivova (MPS Göttingen)

George King

University of Warwick

A010 – ORAL PRESENTATION

XMM-Newton Observations of the HD189733 System

Detections of transits at X-ray wavelengths have the potential to probe the evaporation of planetary atmospheres, providing information that is complementary to ultraviolet observations. X-ray transits can also probe the structure of stellar coronae. To date, there has only been one marginal detection of an X-ray transit, which was made using Chandra and XMM-Newton observations of the prototypical transiting hot Jupiter HD 189733b. We revisit this system at X-ray wavelengths with an XMM-Newton large programme covering twenty primary transit epochs. We will present preliminary findings of our transit search and compare the X-ray light curves with optical and infrared transit observations. We will also compare our data with theoretical studies of coronal transits.

James Kirk

University of Warwick

A030

Characterising exoplanet atmospheres as part of the LRG-BEASTS survey

Studies of exoplanet atmospheres have revealed a startling diversity between systems, with many showing clouds and hazes which mask pressure-broadened absorption features. In the small sample of planets studied to date, no strong correlation has emerged between key planetary parameters and the presence, or absence, of clouds and hazes, although there is evidence that temperature might play a role. In order to characterise this diversity and unravel the underlying physical processes, it is essential that we expand the current sample of studied planets. This is the focus of the Low Resolution Ground-Based Exoplanet Atmosphere Survey using Transmission Spectroscopy (LRG-BEASTS, “large beasts”). To date, this survey has revealed hazes in the atmospheres of HAT-P-18b and WASP-80b, and clouds in the atmosphere of WASP-52b. I will present the latest results from LRG-BEASTS which is pioneering the use of 4-metre class telescopes for transmission spectroscopy.

Stefan Kraus

University of Exeter

A083 – ORAL PRESENTATION

Imaging planet formation signatures in protoplanetary discs

The radial drift problem constitutes one of the most fundamental problems in planet formation theory, as it predicts particles to drift into the star before they are able to grow to planetesimal size. Dust-trapping vortices have been proposed as a possible solution to this problem, as they might be able to trap particles over millions of years, allowing them to grow beyond the radial drift barrier.

In this talk we will present the results from our multi-wavelength, multi-epoch high-angular resolution imaging campaign on the pre-transitional V1247 Orionis . Our observations cover the wide wavelength range from the visible (VLT/SPHERE), near-infrared (VLTI/AMBER, VLT/NACO, Keck/NIRC2, Subaru/HiCIAO), mid-infrared (VLTI/MIDI, Gemini/TReCS), to the sub-millimetre (ALMA, SMA). We detect extreme asymmetries on scales from about 5 to 150 astronomical unit (au) that we interpret as signposts of ongoing planet formation in the system.

Our ALMA 0.04"-resolution imaging reveals a ring-shaped inner disk component with a prominent asymmetry and a sharply confined crescent structure, resembling morphologies seen in theoretical models of vortex formation. The asymmetric ring (at 0.17"=54 au separation from the star) and the crescent (at 0.38"=120 au) seem smoothly connected through a one-armed spiral arm structure found in scattered light. We propose a physical scenario with a planet orbiting at about 0.3" (=100 au), where a one-armed spiral arm detected in polarised light traces the accretion stream feeding the protoplanet. The dynamical influence of the planet clears the gap between the ring and the crescent and triggers two vortices that trap mm-sized particles, namely the crescent and the bright asymmetry seen in the ring. The observation provide a 5...6 times higher angular resolution than earlier observations of candidates for dust-trapping vortices. V1247 Orionis also represents the first case where two vortices might have been observed in the same system, near the inner/outer edge of a density gap.

We conducted dedicated hydrodynamics simulations of a disc with an embedded planet, which results in similar spiral-arm morphologies as seen in our scattered light images. At the position of the spiral wake and the crescent we also observe CO (2-3) and HCO+ (4-3) excess line emission, likely tracing the increased scale-height in these disc regions.

At near-infrared wavelengths we detect a strong asymmetric structure that moved in position angle (PA) from -52°to +38° within 22 months, consistent with Keplerian motion of a companion on an 5 au orbit. This companion candidate is located too close to trigger the dust traps, but might be responsible for clearing the region inside the ring observed with ALMA and VLTI.

Kristine Wai Fun Lam

University of Warwick

A066

Time variability in the evaporating atmosphere of WASP-12 b

Close-in exoplanets are susceptible to increased stellar irradiation. This energy heats up the planetary atmosphere, causing the material to evaporate and escape into the planet orbit and form a comet-like tail. Under suitable conditions, stellar light is absorbed passing through the tail and can be manifested by hiding the emission feature in the Ca II H & K profiles. WASP-12 hosts an evaporating close-in planet and an enhanced absorption is seen in the Ca II H & K. We present a detailed study of WASP-12 spectra observed around the planet orbit to understand the orbital variation of the system and how the system evolves.

Graham K.H. Lee

University of Oxford

A091

Assessing cloud particle seed formation across the brown dwarf and exoplanet regimes

The cloud formation process starts with the formation of seed particles, after which, surface chemical reactions grow or erode the cloud particles. If seed particles do not form, or are not available by another means, an atmosphere is unable to form a cloud complex and will remain cloud free. We investigate which materials may form cloud condensation seeds in the gas temperature and pressure regimes (T_{gas} = 100-2000 K, p_{gas} = 10^{-8}-100 bar) expected to occur in planetary and brown dwarf atmospheres. We calculate the seed formation rates of TiO_2[s] and SiO[s] and find that they efficiently nucleate at high temperatures of T_{gas} = 1000-1750 K. Cr[s], KCl[s] and NaCl[s] are found to efficiently nucleate across an intermediate temperature range of T_{gas} = 500-1000 K. We find CsCl[s] may serve as the seed particle for the water cloud layers in cool sub-stellar atmospheres. Four cold temperature ice species, H_2O[s/l], NH_3[s], H_2S[s/l] and CH_4[s], nucleation rates (T_{gas} = 100-250 K) are also investigated for the coolest sub-stellar/planetary atmospheres. All species require significant supercooling from their S = 1 phase equilibrium zone, with Cr[s] requiring the largest supercooling of ΔT_{cool} =500-700 K before efficient nucleation occurs.

Laura Lewis

Open University

A097

Carbon Planets or Carbon Cores?

Our own Solar System generally consists of two types of planets, the terrestrial planets (Mercury, Venus, Earth and Mars) and the gas giants (Jupiter, Saturn, Uranus and Neptune.) The terrestrial planets of our system are known as “oxygen planets” as they are primarily composed of silicate compounds.Þxoplanets (planets that orbit stars outside our Solar System) do not always fit neatly into the two categories of our system. Due to their density, a certain number of exoplanets may be composed of exotic materials. One such type of planet has come to be called a “carbon planet” as models suggest that the majority of the planet’s mass is made from carbon compounds. One such planet is 55 Cancri e, which lies approximately 40 light years from our Solar System. The 55 Cancri system is populated by planets that are close to the mass of Neptune, and would be classed as giant planets. The innermost planet, e, is very different and is close to 8 Earth masses. A planet of this size would be classed as a “Super Earth” due to its possibly rocky composition and size. Studies of the system show that it is very likely that the planet, e, has undergone significant changes in its position relative to its star since formation due to interaction with the neighbouring planets. It is suggested that this planet originally formed as a gas giant and due to relocation nearer the star has lost its thick gaseous atmosphere to Roche Lobe Overflow (RLO), leaving behind a rocky core. Data from the Hubble Space Telescope (HST) suggests that the atmosphere of this planet contains Hydrogen Cyanide, (HCN) indicating a carbon rich environment.

Referring to the work of (Valsecchi et al., 2014), the orbits of hot Jupiters (large gas giants with short period orbits) in exoplanetary systems may decay as far as the Roche limit

through tidal dissipation by a slowly rotating parent star. Calculations reveal that the transformation of a hot Jupiter into a "Super Earth" core remnant may be relatively fast. The removal of the atmosphere of these gas giants may occur over the timescales of giga years. Orbits of such altered planets are speculated to between hours several days. To prove such claims though, there should be planets that can be observed in the process of transformation. These planets are known as "hot Neptunes" and could potentially be found at the Roche limit, their mass being siphoned off via Roche overflow. There are a large number of planets that have been detected with very short orbital periods, close to the Roche limit. The theory that a hot Jupiter could be converted to a smaller planet via Roche overflow is studied in this paper (possibly a hot Neptune or a super Earth).

Although this paper discusses the formation of Super Earths via Roche Lobe overflow, another work (Valsecchi et al., 2015) predicts an anti-correlation between mass and orbital period. This means that, according to their models, planets under 5 Earth masses with periods under 1 day could not form via RLO of a gas giant.

New simulations from the work of (Jackson et al, 2016) detail that hot Jupiters in short period orbits are prone to spiral inwards to their parent stars due to tidal effects. The processes of orbital dynamics and Roche Lobe overflow could possibly be the cause of the large population of close in exoplanets and possibly also be the production mechanism of the short period rocky exoplanets. In this work, Jackson et al uses the Modules for Experiments in Stellar Astrophysics (MESA) suite to simulate RLO of gas giants. It is found within these simulations that the evolution of a gas giant's orbit depends heavily on the initial mass of the core of the planet. The models are then compared to observations of small, close in exoplanets and enough evidence is obtained to come to the conclusion that a number of the rocky exoplanets are the remnants of gas giants. This is significant for two reasons, firstly, it highlights a mechanism of rocky planet formation and also allows us to study the cores of gas giants.

(Taken from an undergraduate project and current research by Laura Lewis)

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Jackson, B., Jensen, E., Peacock, S., Arras, P. and Penev, K. (2016) 'Tidal decay and stable Roche-lobe overflow of short-period gaseous exoplanets', Celestial Mechanics and Dynamical Astronomy, doi: 10.1007/s10569-016-9704-1.

Tim Lichtenberg

ETH Zürich

A052 – ORAL PRESENTATION

Gradual desiccation of rocky protoplanets from aluminum-26 heating

We model the accretion and delivery of water to extrasolar terrestrial planets from planetesimals heated by the decay of the short-lived radionuclide aluminum-26, that is inherited from the host star-forming environment. We find the final planet water fractions to

be negatively correlated with aluminum-26 abundance and the average size of water-rich planetesimals. Bulk water abundances crucially alter the thermochemical, geodynamic and atmospheric evolution of terrestrial planets. Studies of water delivery to planets in the terrestrial zone of planetary systems predict mean water abundances orders of magnitude higher than observed for bulk Earth, which may negatively affect the ‘habitability’ of fully-fledged planets. We combine time-dependent models of planetesimal dehydration due to radiogenic heating with planet population synthesis calculations. We consider variation in the initial aluminum-26 abundance and planetesimal size, and compute the effects on the exoplanet ensemble. Planetary systems with aluminum-26 abundances similar to or higher than solar system levels tend to form planets that are significantly water-depleted relative to model outcomes where degassing is not taken into account. These findings demonstrate the sensitivity of potential observables, like planet mass and water abundance, on initial levels of radiogenic aluminum-26, and thus the link between the host star-forming environment and planet composition after accretion.

Stefan Lines

University of Exeter

A006 – ORAL PRESENTATION

Exo-Nephology: Synthetic observations of 3D, dynamic clouds in HD209458b

Recent Hubble Space Telescope observations of hot-Jupiter atmospheres have revealed a continuum in atmospheric composition from cloudy to clear skies (Sing et al. 2016). The presence of clouds can be inferred from a grey opacity in the near-IR and/or strong scattering in the visual; both muting key absorption features in the transmission spectra. This observational challenge inhibits the retrieval of key information including the atmospheric chemical composition and thermal structure. In our 3D, radiative-hydrodynamical simulations of the atmosphere of HD209458b, we couple a kinetic, microphysical cloud model (see Helling et al. 2013) to the Met Office's Global Circulation Model, the 'Unified Model'. We consider cloud nucleation, growth, advection, evaporation, gravitational settling, absorption and scattering; the completeness of the radiative transfer (i.e. inclusion of scattering) and the dynamics provided by our new model representing the most physically complete theoretical tool for the study of hot-Jupiters. In addition to analysing the cloud evolution and structure, we investigate the radiative implications of the cloud, on observations, by presenting spectral energy distributions, phase curves and transmission spectra, and assess the possibilities for indirect and direct cloud detection with the James Webb Space Telescope.

Tom Louden

University of Warwick

A031

A ground based transmission spectrum and spectroscopic phase curve of WASP-19b

WASP-19b has emerged as an important window into the physics of hot jupiter atmospheres after it was recently found to be the first planet to show a clear signal of titanium oxide in transmission (Sedaghati et al 2017). The planet also shows evidence of sodium absorption, and a blue scattering haze of unknown origin.

Titanium Oxide has major implications for the structure of exoplanet atmospheres, as it has the potential to lead to a temperature inversion and the formation of a stratospheric layer. It is therefore vital to independently confirm the presence of this important molecule. We present high precision spectroscopic observations of two consecutive transits, we also observed a secondary transit and an almost complete phase curve of WASP-19b.

We will describe a new technique for analysing differential lightcurves that can significantly reduce the amount of photon noise present in the data. A Gaussian process approach is used to detrend the remaining systematics from the data. This results in a precise transmission spectrum from 400-900nm.

We perform an independent test for the presence of TiO and a Rayleigh scattering slope in the atmosphere. In addition, we place constraints on the geometric albedo and thermal emission as a function of wavelength from the secondary eclipse and spectroscopic phase curve.

Ryan MacDonald

University of Cambridge

A055 – ORAL PRESENTATION

Evidence of Nitrogen Chemistry in Hot Jupiter Atmospheres

Detections of carbon, hydrogen, and oxygen-bearing molecules in exoplanetary atmospheres are now routine. Nitrogen-bearing molecules have been anticipated to have low abundances in hot Jupiter exoplanets, often leading to their exclusion from spectral analyses. We will present results from a new atmospheric retrieval analysis searching for nitrogen-bearing molecules in nine exoplanetary atmospheres. Our results include evidence of enhanced NH_3 in WASP-31b and HCN in WASP-63b, both at >2 sigma confidence. Avenues to increase detection significances of nitrogen-bearing molecules with future observations will be offered. These inferences provide observational evidence for disequilibrium chemistry in hot Jupiter atmospheres.

Christopher Manser

University of Warwick

A065 – ORAL PRESENTATION

A planetesimal orbiting a white dwarf on a two-hour period

A large fraction of white dwarfs host remnants of planetary systems, inferred from the detection of photospheric metal pollution and circumstellar discs arising from the tidal disruption of planetesimals. However, transits from a fragmenting planetesimal have only been detected in one system. I will report on the identification of a stable, two hour period in the strength and shape of the emission profiles originating from the gaseous debris disc around a metal polluted white dwarf. This is the first spectroscopic detection of a short period (~hours) signal at a white dwarf hosting a debris disc. I argue that this signal is the orbital period of a solid body with significant internal strength orbiting within the debris disc. I also suggest that the gaseous disc in the system is generated by this body, either from sublimation or by interactions with the dust, and speculate that all observable gaseous debris discs host a closely orbiting planetesimal. I will finally discuss the possible links with other debris disc systems, which may also host planetesimals in close orbit.

Barry Mant

University College London

A098

Hydrocarbon Line Lists

Hydrocarbons are an important constituent of the atmospheres of planets and moons in our solar system. They are thus likely to be important for exoplanetary atmospheres and indeed methane has already been detected on an exoplanet [1].

The Exomol project [2] provides line lists for molecules of astronomical relevance giving temperature dependent cross sections and absolute line intensities. A methane line list is already part of the database and other hydrocarbons are in the process of being added. We have recently completed an ethylene line list applicable up to 700 K and have almost finished one for acetylene. We are currently at a preliminary stage of calculations on ethane.

Computing these line lists is time consuming however and for larger molecules the standard methods are not yet feasible. Hydrocarbon adsorption spectra also overlap significantly making individual species hard to distinguish. A pragmatic approach to obtaining opacities for these molecules is to make use of experimental data. Here we propose a method which uses room temperature infrared spectra obtained from the PNNL database but made temperature dependent.

1.Swain M. R., Vasisht G., Tinetti G., 2008, Nature, 452, 329

2. Tennyson J., et al., 2016, J. Mol. Spectrosc., 327, 73

Angelica Mariani, David A. Russell, Thomas Javelle, John D. Sutherland

MRC Laboratory of Molecular Biology, Cambridge

A106 – ORAL PRESENTATION

From high-energy atmospheric chemistry to a storable, light-releasable prebiotic activating agent

Investigations into the chemical origin of life have recently benefitted from a holistic approach, integrating elements of organic and inorganic systems chemistry (1-3). By interrogating the geochemical scenario present on the early Earth we could infer plausible chemical pathways, which eventually might refine the environmental conditions that made life possible. In our continuing effort to follow this approach, we considered the interplay of atmospheric gasses, transition metal complexes, simple organic building blocks and a variety of conditions including UV irradiation. Dissolution of atmospheric HCN and coordination of cyanide ions to ferrous ions could have led to high levels of $[Fe(CN)_6]^{4-}$ (ferrocyanide) on early Earth (4), and the chemical and physical properties of ferrocyanide salts and derivatives thereof might have supported relevant processes that led to the beginning of life (1,3). We present how an activating agent, namely methyl isocyanide, could have plausibly been produced from simple feedstocks available on early Earth, including $[Fe(CN)_6]^{4-}$. The isocyanide is formed as a stable FeII complex, photolysis of which releases the free activating agent, raising the possibility of spatially and temporally controlled activation chemistry. We further show that methyl isocyanide effectively drives the conversion of nucleoside monophosphates to phosphorimidazolides, apparently ideal candidates for the non-enzymatic synthesis of oligoribonucleotides (5,6), under prebiotically plausible conditions and in excellent yields for the first time. Equally significant to these findings, the environmental conditions required conform to the geochemical scenario we previously outlined for the prebiotic synthesis of amino acids, lipid precursors and pyrimidine nucleotides (3).

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2. Powner, M. W. & Sutherland, J. D. Phil. Trans. R. Soc. B 366, 2870-2877 (2011).

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4. Weimann, B. J., Lohrmann, R., Orgel, L. E., Schneider-Bernloehr, H. & Sulston, J. E. Science 161, 387 (1968).

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Soko Matsumura
University of Dundee

A020

Planet Formation via Pebble Accretion

Planet formation with pebbles has been proposed to solve a couple of long-standing issues in the classical formation model --- the mechanism of planetesimal formation and the timescale of forming a large enough core for the gas accretion. A few groups have performed sophisticated simulations and confirmed the efficiency of pebble accretion in forming various types of planets. However, these studies have not shown whether the pebble accretion scenario can reproduce the observed statistical properties of exoplanetary systems, mainly because such simulations are computationally expensive. We have overcome this problem by adopting the analytical pebble accretion model by Ida et al. (2016) that agrees well with detailed dust growth simulations. We have performed the first global simulations of planet formation via pebble accretion, and compared the resulting systems with observations. In this talk, I will present our results and highlight problems.

Elisabeth Matthews
University of Exeter

A093

Dust Sculptors: Hidden planets in the Dustiest Debris Disk Systems

We have been conducting an imaging survey using VLT/SPHERE, to search for giant planets at wide separations (>10au, beyond the snow line). The transit and RV methods for detecting exoplanets are not sensitive at these wide separations, and so imaging is the only technique allowing us to probe planet frequencies, and understand the formation of these wide separation objects. For a long time, it has been suggested that debris disks might be linked to the presence of planets: dust is quickly removed from a stellar system by stellar

winds or the Poynting-Robertson effect, and so for dust to be observed around stars >~10Myr old it must be constantly regenerated via planetesimal collisions. Not only are these planetesimals the building blocks of giant planets, but in fact the presence of a giant planet will perturb the orbits of planetesimals in the system, making them more likely to collide and producing even more dust. SPHERE is a state-of-the-art high contrast imager, and we have been using this instrument to survey targets hosting debris disk systems, as identified by an IR excess, and also specifically those systems where there is evidence that a debris disk has been carved into multiple, separate rings of dust. The most likely cause of such a gap is the gravitational influence of one or several giant planets. Even further, we can use the dynamical properties of these debris disks to place tight constraints on the system, even if no exoplanets are detected. In this talk I will outline our survey of 24 systems with previously confirmed multi-belt debris disk systems, and describe our results, where we place tight constraints on the planetary systems that are likely to be sculpting the debris dust.

James McCormac
University of Warwick

A003 – ORAL PRESENTATION

NGTS: Current status, new discoveries and the TESS era

The Next Generation Transit Survey has been searching for exoplanets from Paranal since April 2016. The twelve telescopes have obtained over 110 billion photometric measurements. Our first exoplanet was recently published: NGTS-1b, a rare giant planet orbiting an early M-star. I will present the current status of the project along with the latest series of exoplanet discoveries and our plan for the future of NGTS in the era of TESS. Our first public data release is expected in April 2018, when we will release photometry from over 3.5 million images in 39 fields. Light curves for all stars with I-band magnitudes <16 will be made public through the ESO archive after a 1 year proprietary period.

Colin McNally
Queen Mary, University of London

A099 – ORAL PRESENTATION

Wind driven protoplanetary discs and how planets move in them

Protoplanetary discs are believed to accrete onto their central T Tauri star because of magnetic stresses. At the same time, planets form in these discs and are forced to radially migrate when subject to unbalanced torques from the disc gas, contributing to the final architecture of the planetary system. Simulations indicate that the non-ideal MHD of the very poorly ionised disc plays an important roles in its evolution. In the presence of a vertical magnetic field, the disc remains laminar between 1–5 au, and a magnetocentrifugal disc wind forms that provides an important mechanism for removing angular momentum. Although not unstable to the magnetorotational instability, the laminar dead zone can be threaded by large laminar magnetic fields which exert a accretion driving stress at the midplane. Motivated by these models, we have re-examined low mass planet migration in such an environment. Our results show that planet migration torques in a inviscid disc threaded with a magnetic field are phenomenologically different from those previously considered in a traditional viscous accretion disc. We have predicted, and then

experimentally demonstrated the existence of four regimes of low-mass 'Type-I' migration, including a rapid outward migration. In addition, we demonstrate that midplane magnetic stresses induce a bifurcation dependent on the disc surface density leading to torque and migration reversal.

Farzana Meru

Institute of Astronomy, Cambridge

A051

Observational predictions of migrating planets

Recent ALMA observations are showing that dust rings are quite ubiquitous in protoplanetary discs. We investigate the dust rings formed by the presence of a planet in a protoplanetary disc. In particular, we explore, for the first time, how a migrating planet affects the formation of dust rings. We find that the effect of a migrating planet is very different to a stationary planet, which up until now has been the commonly used set up for exploring the effect of planet interactions on the dust in protoplanetary discs. We find two key difference:

1) as well as a dust trap forming exterior to the planet, as seen in stationary planet simulations, the planet causes an additional pressure trap to form interior it;

2) the inner dust trap is dominant for small sizes while the exterior ring is dominant for large sizes.

This causes the dust ring to move significantly as the dust size increases. We show how multiwavelength observations may well predict, for the first time, the presence of a migrating planet.

Jake Morgan

University of Manchester

A073

SPEARNET: Developing a Metric for Exoplanet Transmission Spectroscopy Studies

At present, exoplanets that are widely known to be good for transmission spectroscopy are chosen by observers/groups based on their individual merit, with some of these efforts attempting to rank planets by expected signal-to-noise ratio, or some other desirable characteristic. Upcoming surveys such as TESS and the NGTS will likely provide many thousands of new transiting planets, and their subsequent characterisation will be limited by available resources. For unbiased statistical studies it is important to seek a target selection policy which is objective and quantifiable. SPEARNET (Spectroscopy and Photometry of Exoplanet Atmospheres Research NETwork) is using a heterogeneous telescope network to study exoplanet atmospheres chosen through a selection metric.

I will discuss the development and tuning of our selection metric and its utility in comparing instruments for single-target use, as well as for selecting populations of the most promising planets for further study in the context of a wider software pipeline.

Rebecca Nealon

University of Leicester

A075 – ORAL PRESENTATION

Warped discs by misaligned planets

Current observations from ALMA have identified unique features in protoplanetary discs around young stars, including warps in the disc (e.g. TW Hya, HD 100453 and HD 135344B) and strongly misaligned inner discs (e.g. HD 100546). For these systems in particular, observations rule out the influence of a secondary star suggesting that as yet unseen planets may be the cause. A planet that is capable of driving these features in the disc would be required to maintain an orbit that is inclined to the disc plane on long timescales, in contradiction with analytical expectations and current planet formation theory. Our initial investigation focuses on the evolution of a planet on an inclined orbit using 3D numerical simulations. We will present these results and consider the significance of the disc structures found using synthetic observations.

Richard Nelson

Queen Mary, University of London

A094

Evolution of circumbinary planets embedded in circumbinary discs: Understanding the origins of the Kepler circumbinary planets

Approximately 11 circumbinary planets have been discovered by the Kepler mission. These planets orbit both stars in close binary systems, and a combination of transit light curve analysis, timing analysis and stellar spectroscopy can provide exquisite constraints on the physical characteristics of these systems. A significant number of the planets, including Kepler-16b, -34b, -35b, are found to orbit very close to the zone of dynamical instability that exists close to the central binary, raising interesting questions about their origins. Furthermore, all planetary orbit planes, except those of Kepler-413b and -453b, are highly coplanar with those of the central binary. During my talk, I will present the results from recent 2D and 3D hydrodynamic simulations of planets embedded in circumbinary discs that aim to examine whether or not the orbital configurations of the known circumbinary planets match theoretical expectations.

Lena Noack

Institute of Earth Sciences, Free University Berlin

A072 – ORAL PRESENTATION

Mantle and atmosphere evolution depending on planet mass and composition

Thousands of exoplanets have been discovered in the past decade, revolutionizing our way of scientific thinking both in the direction of formation and evolution of planets, as well as in the direction of exotic places where life may evolve and flourish in non-Earth-like environments. However, identification of possible atmosphere biosignatures or models of the evolution of exoplanets are typically based on Earth models - which is a natural first step to understand processes on possibly habitable planets, especially since we are more prone to detect exo-life (if it exists) on Earth-like planets than on other planets due to our detection bias.

Several studies for example extrapolated Earth models to other planet properties (e.g. mass, radius, core size) to predict how basic planetary processes (like mantle convection or plate tectonics) are affected by these parameters. However, even if a planet is discovered with a density hinting at a rocky planet, it may be quite non-Earth-like for example in terms of composition, mineralogy, core formation, volatile content, etc. Within the range of uncertainties and with the current observation techniques, it is impossible to differentiate remotely between a planet like Earth with continents and oceans at the surface, or a dry one-plate planet, or an ocean planet, or exotic planets like carbon-rich ("diamond") planets.

It is therefore necessary to study how the evolution of a planet may be affected by the unknown planet's properties as well as its formation and evolution history, and to understand better possible restrictions for surface or subsurface habitability. The composition of the mantle has a strong influence on the mantle convection (and possibly plate tectonics initiation or maintenance), as well as on the crust and atmosphere evolution (based on volatile-dependent melting temperatures and melt compositions). A dense-enough atmosphere would be needed to preserve surface water for planets in the habitable zone. We find that the interior composition and structure (especially in terms of water content and core-mass fraction) as well as the planet's size strongly influence the outgassing potential and build-up of a secondary atmosphere.

Stochastic Monte-Carlo models of possible planet post-formation-states and planet compositions are used in this study to predict the range of possible evolution trends for specific rocky planets, and can be used to help identifying exoplanets of higher (or lower) interest to expensive follow-up observations.

Hugh Osborn

Laboratoire d'Astrophysique de Marseille

A023

Old vs New - Comparison of Transit Signal Vetting

ESA's PLATO mission will benefit from large quantities of ground-based follow-up efforts. However, to efficiently delegate telescope time, classification and ranking of exoplanetary candidates must be performed in order to remove false positives and ensure the most scientifically valuable planets receive the most telescope time. Such a process must also be performed relatively rapidly and be computationally efficient.

Here, I will show preliminary results on candidate vetting, and compare both a classical “flag”-based vetting approach and a machine-learning based approach with Kepler data & detection catalogues. Both involve turning key data such as centroid, light curves, stellar information, etc into an estimate of the source of the signal, with the “flag” vetting involving the generation of measured quantities from the available data (such as phase, eclipse, transit duration), and the convolutional neural network approach uses simply the raw data and a large training set to estimate the class of the transit event. This can be applied to both TESS & PLATO candidates in the future.

James Owen

Imperial College London

A087 – ORAL PRESENTATION

The role of atmospheric escape and host star metallicity in the origin and evolution of super-earths

Many stars host close-in super-earth planets. I will use data from the California Kepler Survey to argue that the properties of these planets are driven by a combination of formation and atmospheric escape. The star's metallicity tells us about the amount of solid material that existed in the planet-forming nebula. We find higher metallicity stars (which had higher solid abundances) form more massive planets, which accrete more nebula gas. After the planet formation process finishes the evolution of a planet is driven by the loss of its H/He atmosphere it originally accreted from the nebula. This evolution results in two types of planets: those that retain their "primordial" atmosphere and those that completely lose it. The evolution produces a bimodality in the planetary radius distribution that was recently observed by the California Kepler Survey. The properties of the bimodal radius distribution are extremely sensitive to the initial properties of the planets after formation. Using planetary evolution models including atmospheric escape I will unveil the properties of the planet properties at "birth".

Vivien Parmentier

Laboratoire d'Astrophysique de Marseille

A047 – ORAL PRESENTATION

Re-interpreting the spectrum of ultra-hot Jupiter atmospheres by including molecular dissociation and cloud formation: the case of WASP-121b into context

Hubble and spitzer space telescope observations of ultra-hot hot Jupiters (Teq>2000K) have revealed a lack of strong molecular features similar to the ones seen in cooler hot Jupiters (Teq<2000K). Many explanations have been proposed for these blackbody-like spectra, including the presence of a quasi-isothermal dayside atmosphere, the presence of a high C/O ratio or the presence of non-solar abundance ratio between water and other molecules such as VO or FeH. Using the case of WASP-121b, I will show that at these high temperatures the thermal dissociation of water fundamentally shapes the emission spectra. Considering the vertical gradient of water and the presence of additional molecules predicted by chemical equilbrium calculations, I will show that both the emission and the transmission spectra of WASP-121b can be well reproduced by the outputs of a global circulation model assuming solar abundances and taking into account molecular dissociation and condensation of material at the limb of the planet. Finally, I will put WASP-121b into context, and discuss for which planets molecular dissociation is going to play a fundamental role and needs to be incorporated into atmospheric retrieval models.

Hannu Parviainen

Instituto de Astrofísica de Canarias

A103

MuSCAT2

We present MuSCAT2, a new instrument capable of simultaneous asynchronous four-colour imaging installed in the 1.5~m Telescopio Carlos Sanches (TCS) at the Teide Observatory, Tenerife. MuSCAT2 has been developed by the Astrobiology Center and University of Tokyo (P.I. Norio Narita) in collaboration with the IAC (P.I. Enric Palle), and its primary science case will be multicolour photometry of exoplanet (candidate) transits.

MuSCAT2 is offered as a common-user instrument in the TCS, but science topics related to extrasolar planets are protected. However, we are happy to collaborate in exoplanet-related science, and strongly encourage anyone interested to use the instrument to contact with the PIs.

Mark Philips

University of Exeter

A058

Cloudless Atmospheres for Brown Dwarfs and Giant Extra-Solar Planets

The presence of condensate clouds in the atmospheres of brown dwarfs and exoplanets is the generally accepted explanation for a wide range of observations, including the L-T brown dwarf spectral sequence and the extremely red near-infrared spectra of young planetary mass objects. However, issues still remain with this cloudy scenario. The physical process driving the inferred disappearance of clouds at the L-T transition is unclear, and reproducing the extremely red spectra of young objects with radii consistent with evolutionary models continues to be a challenge. This motivates our research into an alternative ‘cloud-free’ scenario. We suggest that brown dwarfs may be subject to a thermo-chemical instability induced by non-equilibrium chemistry, which can alter the temperature profile of the atmosphere and provide an alternative explanation for their spectral evolution. I will present new results from the development of a cloud-free grid of model atmospheres generated using our 1D forward model ATMO. I will show that our model can adequately reproduce the near-infrared spectra of benchmark objects throughout the L-T spectral sequence, suggesting that while clouds are present in brown dwarf atmospheres, they may not be driving the spectral evolution. We also find that we can reproduce the spectra of young objects with radii consistent with their age. These results highlight how processes other than clouds can have significant influence on the spectra of brown dwarfs and giant exoplanets. Finally, I will discuss future work which could help distinguish between the cloudy and cloud-free scenarios.

Arazi Pinhas
Institute of Astronomy, Cambridge

A009 – ORAL PRESENTATION

Chemical abundances and cloud properties in ten hot giant exoplanets and implications for their formation conditions

Transmission spectroscopy of exoplanets has the potential to provide precise measurements of atmospheric chemical abundances, in particular of hot Jupiters whose large sizes and high temperatures make them especially conducive to such observations. We will present new results from a comprehensive and homogeneous retrieval analysis of state-of-the-art broadband spectra for a sizable sample of hot giant exoplanets. In particular, we will report detailed estimates of chemical abundances, cloud properties and temperature profiles for all the ten planets, as well as the detection significances for the chemical species. The chemical abundances thus derived can provide important constraints on the formation and migration pathways of hot giant exoplanets and we will discuss the possible differences in formation conditions between solar and hot extrasolar giant planets. Our study demonstrates the promise of high-precision and broadband transmission spectra to constrain atmospheric properties of exoplanets with HST and upcoming facilities such as JWST.

Benjamin Pope
New York University

A092

Detection of Oscillations in Aldebaran

The nearby red giant Aldebaran is known to host a gas giant planetary companion from decades of ground-based spectroscopic radial velocity measurements. Using Gaussian Process-based Continuous Auto-Regressive Moving Average (CARMA) models, we show that these historic data also contain evidence of acoustic oscillations in the star itself, and verify this result with further dedicated ground-based spectroscopy and space-based photometry with the Kepler Space Telescope. From the frequency of these oscillations we determine the mass of Aldebaran to be 1.16 +- 0.07 solar masses, and note that this implies its planet will have been subject to insolation comparable to the Earth for some of the star's main sequence lifetime. Our approach to sparse, irregularly sampled time series astronomical observations has the potential to unlock asteroseismic measurements for thousands of stars in archival data, and push to lower-mass planets around red giant stars.

Ken Rice
University of Edinburgh

A053

On the fragmentation of turbulent self-gravitating discs in the long cooling time regime

It has recently been suggested that in the presence of driven turbulence discs may be much less stable against gravitational collapse than their non turbulent analogs, due to stochastic density fluctuations in turbulent flows. This mode of fragmentation would be especially important for gas giant planet formation. Here we argue, however, that stochastic density fluctuations due to turbulence do not enhance gravitational instability and disc fragmentation in the long cooling time limit appropriate for planet forming discs. These fluctuations evolve adiabatically and dissipate away by decompression faster than they could collapse. We investigate these issues numerically in 2D via shearing box simulations with driven turbulence and also in 3D with a model of instantaneously applied turbulent velocity kicks. In the former setting turbulent driving leads to additional disc heating that tends to make discs more, rather than less, stable to gravitational instability. In the latter setting, the formation of high density regions due to convergent velocity kicks is found to be quickly followed by decompression, as expected. We therefore conclude that driven turbulence does not promote disc fragmentation in protoplanetary discs and instead tends to make the discs more stable. We also argue that sustaining supersonic turbulence is very difficult in discs that cool slowly.

Paul Rimmer

University of Cambridge

A080

Simulating the Starlight on Rocky Exoplanets

The origin of the building blocks of life on the Early Earth was likely photochemical (Sutherland 2017). This same origin can work with varying degrees of success on the surfaces of exoplanets around stars of different types. This allows us to identify an 'abiogenesis zone', within which the building blocks of life can be produced photochemically as efficiently on an Earth-like exoplanet around a different kind of star as on the Early Earth. We made an estimate of the location of this zone using mecury lamps (Rimmer et al, Submitted). These are the same lamps used to explore the chemistry on the Early Earth. But mercury lamps do not look like the young Sun, or any other star.

We have constructed a simulator using a Xenon lamp, lenses and filters, that can accurately simulate the 200-400 nm spectral irradiance for a variety of stars, impinging on the surface of a rocky exoplanet with an atmosphere of arbitrary composition. The simulator can also be set up to reproduce the variability in the 200-400 nm flux due to flares. We discuss how the simulator works and how it can be modified to simulate a variety of environments. We also plan to present new reactions discovered using this simulator as well as an updated abiogenesis zone determined by applying this more accurate spectral irradiance to the reactions from Rimmer et al (Submitted).

Co-authors: Samantha J Thompson, Jianfeng Xu, John D Sutherland, Didier Queloz

Citations:

Rimmer, P B, Xu, J, Thompson, S, Gillen, E, Sutherland, J D, Queloz, D. The Origin of RNA Precursors on Exoplanets. Submitted to Science Advances.

Sutherland, J. 2017. Studies on the origin of life – the end of the beginning. Nature Reviews. 0012(1),1.

Samuel Roberts

University College London

A082 – ORAL PRESENTATION

Selective prebiotic synthesis of Watson-Crick pyrimidine and purine arabino-furanosyl-nucleosides in water

Replication is a fundamental requirement for life, and nucleic acids underpin the molecular foundation of replication in all extant biology. The universally conserved role of nucleic acids across all domains of life, suggests they were also vital at the origins of life as both genetic and functional molecules. However, the origins of biopolymers that could have evolved to furnish modern biological replication and the prebiotic synthesis of their constituent building blocks has been a major stumbling block in origins of life chemistry for over 60 years. Here we present the divergent, mutually compatible prebiotic synthesis of a complete set of Watson-Crick base pairing nucleosides. Importantly, we observe that ultraviolet light mediated reduction is selective for canonical over non canonical purine bases. These UV requirements may present another tool for narrowing the search for habitable exoplanets.

Giovanni Rosotti

Institute of Astronomy, University of Cambridge

A088 – ORAL PRESENTATION

Unveiling the youngest exoplanet population

Thanks to the exquisite spatial resolution of ALMA, a rich morphology of gaps, rings and spirals is being uncovered in proto-planetary discs. The most compelling explanation for their origin is that they are the signposts of young, forming planets. In this hypothesis, I will discuss what are the masses and locations of the planets implied to explain the observed structures. I will highlight in particular how to derive from observation of gaps and rings accurate measurements of the mass of the perturbing planet. The limit on how well we can measure this mass comes from our limited knowledge of the disc conditions (in particular of the disc viscosity), ultimately limiting the precision to a factor of 2-3. Alternative explanations for these structures, not involving planets, have however been invoked. I will discuss a possible way to prove or disprove the planetary origin. While most observations have so far focused on the continuum, I will show how ALMA observations of molecular lines can place constraints on the planet mass independently from the continuum. Two very different values of the planet mass would therefore be at odds with the planetary hypothesis.

Sarah Rugheimer

University of St. Andrews

A050 – ORAL PRESENTATION

Pre-Biosignatures in the Atmospheres of Earth-like Planets Around Other Stars

When we observe the first terrestrial exoplanet atmospheres, we expect to find planets at a wide range of geological conditions and evolution. In our own Solar System we already have three very different terrestrial exoplanets in Earth, Mars, and Venus. Additionally the atmospheres of these planets have not been fixed in time. Earth itself offers many possible atmospheric states of a planet. We set out to examine how an Earth-like planet at different geological epochs might look around other star types (F, G, K and M dwarf stars). Additionally, we examine the plausibility of detecting prebiotically interesting molecules, such as HCN, NH_3, CH_4, and C_2H_6 in an early-Earth type atmosphere. We find that some of these molecules could be produced abiotically in a $CO_2/CH_4/H_2$ rich atmosphere with lighting and photochemistry. These molecules would be interesting to detect in an exoplanet atmosphere since they are known to be useful for key prebiotic chemical pathways. HCN, for example, is present at each of the initial photochemical reactions that produce lipids, amino acids and nucleosides, the three building blocks of life (Patel et al. 2015). We also look at the rise of oxygen and the detectability of combinations of biosignature gases throughout Earth history, modeling the great oxygenation event and Neoproterozoic oxygenation event event around other star types. We show the VIS - IR spectral features, with a focus on biosignatures observable through geological time for FGKM stars and the effect of clouds on the signal.

Subhajit Sarkar

University of Cardiff

A038

Effects of star spots on transmission spectra in the ARIEL mission.

Star spots can be a source of uncertainty on the retrieval of planet transit depths. Unocculted spots can increase the effective transit depth, while occulted spots can produce upward distortions in the light curve leading to reduced transit depths on fitting. These effects are both wavelength dependent and thus present a possible issue for accurate interpretation of transmission spectra. Quantification of the impact on the transmission spectra is the first step in assessing the extent of the problem and when detrending or decorrelation techniques may be indicated. We adopt a novel approach combining three simulation packages to investigate the impact of spots and faculae. The ExoSim transit spectroscopy simulator is used to generate simulated observations of a planet crossing a spotted star, producing spectral light curves, which are then processed to construct the emergent transmission spectrum. The spotted star is simulated using the SpotSim model, that incorporates a log-normal spot size distribution function. Using a Monte Carlo approach we can obtain the average wavelength-dependent bias and distribution of transits depths. We can assess impact through comparison of spot bias and noise to the photon noise. We obtain results for the ARIEL instrument channels, using simulated observations of GJ 1214b and HD209458 b. By incorporating the TauRex radiative transfer code we can assess the impact on spectral retrievals, such as the mimicking of Rayleigh scattering. Different spot and faculae spatial and size distributions can be simulated.

Nicole Schanche
University of St Andrews

A040

Machine Learning Methods to Detect New WASP Candidates

Since the onset of the Wide Angle Search for Planets (WASP) program, more than 160 transiting exoplanets have been identified. However, there remains a large number of light curves yet to be analyzed. In order to increase planet search efficiency, a more automated process is needed to parse through the light curves and to identify potential transits. To this end, we have created training and test datasets made up of stellar light curves showing a variety of signal types, including planetary transits, eclipsing binaries, variable stars, and no periodic signal. We use multiple methods of machine leaning such as Random Forest Classifiers (RFCs), Artificial Neural Networks (ANNs), and Convolutional Neural Networks (CNNs) to distinguish between the different types of signals. By combining the predictions of all of the classifiers, we create a prioritized list of candidates for follow-up observations.

Aurora Sicilia-Aguilar
University of Dundee

A089 – ORAL PRESENTATION

Reading between the lines': What time-resolved spectroscopy of young stars tells us about accretion, activity and the innermost disk

Emission lines are one of the defining characteristics of young stars, and carry an overwhelming (and not-so-easy-to-extract) amount of information about accretion and activity processes in the stellar magnetosphere and innermost disk. Using time-resolved spectroscopy covering several rotational and disk orbital periods, we can obtain a very detailed view of the structure and variability of accretion columns and spots and information on the presence and launching points of stellar/disk winds in young stars. Time-resolved emission (and absorption) line spectroscopy can also trace parts of the inner disk at scales that are not accessible by direct imaging or interferometry. Understanding these processes and how they affect the observed spectra can also help us to identify (or rule out) the presence of young and newly-formed planets and stellar companions that may be perturbing the disk. I will present the results for four stars with very different spectral types and behaviours (EX Lupi, GW Ori, ASASSN-13db, and ZCMa), discussing the power and limitations of emission line tomography and exploring what we can learn from "reading between the (spectral) lines" in these and other objects.

Jessica Spake
University of Exeter

A012 – ORAL PRESENTATION

Helium in the extended atmospheres of exoplanets

Helium was predicted to be observable in exoplanet atmospheres by Seager & Sasselov (2000), but no such detections of the element have yet been published. The metastable (2^3S) state of helium forms in upper planetary atmospheres, and presents a new method to study extended and escaping exoplanet atmospheres, that is complementary to the Lyman-alpha and H-alpha lines. I'll present new results from HST exoplanet transmission spectroscopy that covers the 10830A line, and discuss how JWST/TESS will allow us to explore the extended atmospheres of both a large number of planets, and potentially super-Earth planets in the near future.

Jacob Swett

University of Oxford

A007

Interstellar Missions & In Situ Exoplanet Magnetometry: Status and Prospects

The Breakthrough Starshot Initiative was established in 2016 with the aim of using laser-driven spacecraft to reach the Sun's nearest stellar neighbour, Proxima Centauri, by approximately 2065. This hugely ambitious project offfers the tantilising prospect that in-situ observations of Proxima b may become possible within the coming decades. Although there currently exists no possibility of deceleration on arrival, the intended steering mechanisms should allow for a point closest approach less 1AU from the planet, offering the chance for higher resolution measurements than are possible from Earth. It is envisaged that many of these probes will be launched, enabling a thorough probing of the region aound the planet and star.

The extreme limitations on payload and transmission capacity mean that optimisation of instrumentation choices is more significant then on any other space mission to date. We suggest that a key component of any such probes is a set of magnetometers.

This presentation will outline the science case for inclusion of such sensors on the spacecraft, focussing on what magnetic field measurements of Proxima b might elucidate. A number of in-Solar Sytem preliminary testing missions are currently under consideration, including an Europa orbiter and investigations of the outer heliosphere. We will discuss the potential applications of magnetometry to such missions as well.

Jacob Swett

University of Oxford

A036

The Breakthrough Initiatives: Scientific Explorations of Exoplanets

The Breakthrough Initiatives was founded in 2015 by Yuri Milner to explore the Universe, seek scientific evidence of life beyond Earth, and encourage public debate from a planetary perspective. The initiatives comprise three areas: StarShot, Listen, and Watch - which focus on interstellar missions, radio astronomy observations, and optical observations respectively. This poster will provide an overview of the three initiatives, with a particular emphasis on exoplanets and the associated scientific mentions.

Breakthrough Starshot aims to demonstrate proof of concept for ultra-fast light-driven nanocrafts and lay the foundations for a launch to Alpha Centauri within the next generation. Along the way, the project could generate important supplementary benefits to astronomy, including solar-system exploration and detection of Earth-crossing asteroids.

Breakthrough Listen is the largest ever scientific research program aimed at finding evidence of civilizations beyond Earth. The scope and power of the search are on an unprecedented scale.

Breakthrough Watch aims to identify and characterise Earth-sized rocky planets around Alpha Centauri, and other stars within 20 light years of Earth, in search of oxygen and other biosignatures.

Lorna Temple

University of Keele

A064

Discovery of Exoplanets Orbiting Hot, Fast-rotating Stars

The number of confirmed exoplanets is now into the thousands, with the majority of these planets being discovered using the transit method. Until recently, very few transiting exoplanets were found around hot, fast-rotating host stars (with T_{eff} > 6250K), due to the difficulty in obtaining accurate radial velocity measurements for confirmation of the planet's orbit. This has meant that our picture of the formation and evolution of planetary systems is incomplete. Through the use of Doppler tomography, planet search groups are now beginning to populate this previously unexplored subset of potential hosts. The planets in this group differ from their counterparts with later-type hosts: they tend to be in orbits which are misaligned with respect to the stellar rotation and which have periods shorter than the stellar rotation period, implying a different dynamical history. I will present the most recent tomographic confirmations of planets from the WASP-South survey, including WASP-167b/KELT-13b: a retrograde hot Jupiter orbiting an F1V star.

Jean Teyssandier

Cornell University

A021 – ORAL PRESENTATION

Orbital Evolution during planet-disc interactions

The origin and wide distribution of eccentricities and inclinations in planetary systems remain to be explained, in particular in the context of planet-disc interactions. I will present our recent developments regarding the evolution of eccentricity and inclination in discs and planets, based on both a linear theory and direct hydrodynamical simulations. We find that the eccentricity and inclination of giant, gap-opening planets can be excited over long timescales, with consequences on their future dynamical evolution. The disc's large scale structure can also be modified, and I will discuss the various observational consequences of these results.

Niranjan Thatte

University of Oxford

A034 – ORAL PRESENTATION

Direct detection of exoplanets with ELT-HARMONI: adding a high contrast mode

HARMONI is the first light visible and near-infrared integral field spectrograph for the ESO ELT. It is supported by (bright) natural star adaptive optics, and laser tomographic adaptive optics to provide diffraction limited spectroscopy. As part of the preliminary design, we have investigated the design of a dedicated high contrast channel, capable of providing 10^6 contrast at 200 milli-arc-seconds from the parent star.

On behalf of the consortium, I will present the predicted performance (and design) of the high contrast channel. This item is currently unfunded, and we seek feedback from the community on the scientific desirability of this added capability, and possible routes to funding the modest hardware costs.

Samantha Thompson

University of Cambridge

A076

HARPS3 and the Terra Hunting Experiment

We present the current status and a project description of the Terra Hunting Experiment with HARPS3 - a new instrument being built for the Isaac Newton Telescope. HARPS3 is planned to be installed on an upgraded and roboticized Isaac Newton Telescope by end-2019. HARPS3 will be a high resolution (R = 115,000) echelle spectrograph with a wavelength range from 380-690nm. It is being built as part of the Terra Hunting Experiment – a future 10 year radial velocity measurement programme to discover Earth-like exoplanets. The instrument design is based on the successful HARPS spectrograph on the 3.6m ESO telescope and HARPS-N on the TNG telescope. The main changes to the design in HARPS3 will be: a customised fibre adapter at the Cassegrain focus providing a stabilised beam feed, dual-beam full-Stokes polarimeter and an on-sky fibre diameter ~ 1.4 arcsec, the implementation of a new continuous flow cryostat to keep the CCD temperature very stable, characterisation of the HARPS3 CCD to map the effective pixel positions and thus provide an improved accuracy wavelength solution and the instrument integrated into a robotic operation. The robotic operation will optimise our programme which requires our target stars to be measured on a daily basis.

Giovanna Tinetti

University College London

A068 – ORAL PRESENTATION

A chemical survey of exoplanets with ARIEL

Thousands of exoplanets have now been discovered with a huge range of masses, sizes and orbits: from rocky Earth-like planets to large gas giants grazing the surface of their host star. However, the essential nature of these exoplanets remains largely mysterious: there is no known, discernible pattern linking the presence, size, or orbital parameters of a planet to the nature of its parent star. We have little idea whether the chemistry of a planet is linked to its formation environment, or whether the type of host star drives the physics and chemistry of the planet's birth, and evolution.

The Atmospheric Remote-Sensing Infrared Exoplanet Large-survey (ARIEL) is a mission candidate considered by the European Space Agency (ESA) for its next medium-class science mission due for launch in 2026 (M4).

ARIEL will observe a large number (~1000) of transiting planets for statistical understanding, including gas giants, Neptunes, super-Earths and Earth-size planets around a range of host star types using transit spectroscopy in the 1.25-7.8 μm spectral range and multiple narrow-

band photometry in the optical. ARIEL will focus on warm and hot planets to take advantage of their well-mixed atmospheres which should show minimal condensation and sequestration of high-Z materials and thus reveal their bulk and elemental composition (especially C, O, N, S, Si). Observations of these warm/hot exoplanets will allow the understanding of the early stages of planetary and atmospheric formation during the nebular phase and the following few million years. ARIEL will thus aim at providing a representative picture of the chemical nature of the exoplanets and relate this directly to the type and chemical environment of the host star.

For this ambitious scientific programme, ARIEL is designed as a dedicated survey mission for transit, eclipse and phase-curve spectroscopy, capable of observing a large and well-defined planet sample within its 4-year mission lifetime. The ARIEL mission concept has been developed by a consortium of 17 countries.

ARIEL will have an open data policy, enabling rapid access by the general community to the high-quality exoplanet spectra that the core survey will deliver.

Shang-Min Tsai

University of Bern

A105

Disequilibrium Chemistry in Exoplanet Atmospheres

The study of exoplanets has evolved from detection to characterization, thanks to the advent of cutting-edge observational techniques. The spectra of exo-atmospheres provide us with valuable clues about the atmospheric chemistry and thermal structure. Diagnosing and interpreting these spectra to obtain chemical compositions is now at the forefront of exo-atmospheric research. We present a generalised scheme that is able to treat disequilibrium chemistry, as the gaseous species are driven towards chemical equilibrium on a prescribed chemical timescale. This method allows us to study non-equilibrium chemistry in three-dimensional general circulation models.

Angelos Tsiaras

University College London

A019 – ORAL PRESENTATION

A population study of gaseous exoplanets

In the past two decades, we have learnt that every star hosts more than one planet. While the hunt for new exoplanets is on-going, the current sample of more than 3500 confirmed planets reveals a wide spectrum of planetary characteristics. While small planets appear to be the most common, the big and gaseous planets play a key role in the process of planetary formation. I will pesent the analysis of 30 gaseous extrasolar planets, with temperatures between 600 and 2400 K and radii between 0.35 and 1.9 Jupiter radii. These planets were spectroscopically observed with the Wide Field Camera 3 on-board the Hubble Space Telescope, which is currently one of the most successful instruments for observing exoplanetary atmospheres. The quality of the HST/WFC3 spatially-scanned data combined with our specialised analysis tools, allowed us to create the largest and most self-consistent sample of exoplanetary transmission spectra to date, and study the collective behaviour of

warm and hot gaseous planets rather than isolated case-studies. We defined a new metric, the Atmospheric Detectability Index (ADI) to evaluate the statistical significance of an atmospheric detection and find statistically significant atmospheres around 16 planets. For most of the Jupiters in our sample we find the detectability of their atmospheres to be dependent on the planetary radius but not on the planetary mass. This indicates that planetary gravity is a secondary factor in the evolution of planetary atmospheres.

Sam Turnpenney
University of Leicester

A090

Exoplanet-induced radio emission from M dwarfs

We consider the magnetic interaction of exoplanets orbiting M-dwarfs, calculating the expected Poynting flux carried upstream along Alfvén wings to the central star. A region of emission analogous to the Io footprint observed in Jupiter's aurora is produced, and we calculate the radio flux density generated near the surface of the star via the electron-cyclotron maser instability. We apply the model to produce individual case studies for the TRAPPIST-1, Proxima Centauri, and the dwarf NGTS-1 systems. We predict steady-state flux densities of up to ~10 µJy and sporadic bursts of emission of up to ~1 mJy from each case study, suggesting these systems may be detectable with the Very Large Array (VLA) and the Giant Metrewave Radio Telescope (GMRT), and in future with the Square Kilometre Array (SKA). Finally, we present a survey of 85 exoplanets orbiting M-dwarfs, identifying 11 such objects capable of generating radio emission above 10 µJy.

Dimitri Veras
University of Warwick

A085

Full-lifetime simulations of planetary systems

Connecting planetary systems at different stages of stellar evolution helps us understand their formation, evolution and fate, as well as providing crucial insights about dynamics and chemistry. Simulations which combine both planetary and stellar evolution have now progressed to the level where we could include multiple exo-asteroid belts, multiple stars and multiple exo-planets. I will present recent results linking observations to our simulations, both with respect to metal-polluted white dwarfs and to the HD 131399 multiple-star planetary host system. I will also advertise our freely-available code for general use.

Hannah Wakeford
Space Telescope Science Institute, Baltimore USA

A077 – ORAL PRESENTATION

Transmission Spectroscopy in the Age of JWST

Transmission spectroscopy is a powerful tool to measure composition, temperature, and dynamics in the atmosphere of transiting exoplanets. In the last decade, dozens of exoplanets have had their atmospheric properties analysed with ground- and space-based

instruments to determine their global composition and structure. With the launch of JWST in 2019, the field will be expanded further to longer wavelengths, where the important carbon-based species can be observed, and higher precisions, thus allowing us to go to smaller and colder planets. Unlike, HST, JWST will also provide uninterrupted transit lightcurves that fully resole the ingress and egress of the planet as it passes in front of the star. For the first time, we will have high cadence, high precision, high resolution measurements that will be used to disentangle the properties of planetary atmospheres. I will present the planned JWST GTO transiting exoplanet observations from PI M. Mountain, the only GTO program that plans to fully characterize 2 planets (a hot Jupiter and a warm Neptune) from 1-12 microns in both transmission and emission, and discuss the potential uses of JWST for transiting exoplanet characterization.

David Wilson

University of Warwick

A037

Iron-rich planetesimal debris in a post main-sequence planetary system

Planetesimal debris strewn across the photospheres of white dwarfs provide a unique avenue to measure the bulk composition of rocky extrasolar bodies. Using spectroscopy from the Hubble Space Telescope, we have discovered debris with an extraordinary high mass fraction of iron and nickel, suggesting that the planetesimal progenitor was likely a diferentiated asteroid with an iron/nickel core making up the majority of its mass, similar to the asteroid Psyche. We present an overview of our observations and an analysis of the debris composition. Using stellar evolution models, we explore the effects of changes in the stellar luminosity during the giant branches on orbiting rocky objects, and discuss whether this and similar iron-rich planetesimals detected at other white dwarfs are produced by thermal mantle-stripping.

Mark Wyatt

Institute of Astronomy, Cambridge

A025

Delivery of volatiles from outer debris belts to inner planets

It is known that 20% of nearby stars host planetesimal belts orbiting 10s of au from the star. For a growing number CO gas has been detected coincident with the planetesimal belts showing that their planetesimals have a similar composition to Solar System comets. It is expected that some of these planetesimals may be perturbed into the inner regions of the system where they may collide with planets. The hot dust seen in several systems may be evidence of such comet-like dynamics, and in one system this picture is reinforced by the detection of CO close to the CO2 sublimation radius. This talk will present the evidence for the inward delivery of volatile material, as well as numerical simulations of the scattering process that determine the rate at which material is scattered in resulting in accretion onto inner planets, and the effect this has on the planets through volatile delivery and stripping of any primordial atmosphere.

Jack Yates
University of Edinburgh

A035 – ORAL PRESENTATION

Ozone layers on tidally locked M-dwarf planets

The discovery of Earth-sized planets in the habitable zone has been a priority for many years. It is only recently that we have discovered such planets. The orbital configurations of the first candidates are quite different to those in the solar system; these newly discovered planets are on short-period orbits around M-dwarf stars. The lack of a solar analogue means that the habitability impacts of the system configuration - tidal locking and tidal heating, M-dwarf variability and spectra, planetary formation mechanisms - are not fully known.

One of these concerns is the stability of the ozone layer, which shelters organisms from harmful high-energy radiation, has important climate feedbacks and is a potential biosignature. Here we explore ozone chemistry through atmospheric modelling. We have incorporated an online chemistry model into the Met Office Unified Model. We believe this is one of the first exoplanet GCMs to include online chemistry. We have run simulations of Earth-like planets in tidally-locked/3:2 resonant orbits with a simplified ozone chemical mechanism in order to study the effects of the planetary orbit and stellar spectrum on an ozone layer in M-dwarf planet atmospheres. In this talk we will present results from the model runs.

Ben Yelverton
University of Cambridge

A067

Secular resonance sculpting in debris discs

The planetesimals comprising debris discs are dynamically perturbed by planets, and these perturbations heavily influence their spatial distribution; the effects of such planet-disc interactions are evident in our own solar system, for example in the Kirkwood gaps in the asteroid belt, which are in mean motion resonance with Jupiter. Studying the structure of a debris disc can thus be a powerful way to learn about planets that may be present in the system. We present a mechanism for the formation of depleted regions in debris discs via secular interactions with a multi-planet system interior to the disc. The secular resonances of such a system can excite the eccentricities of planetesimals at specific locations in the disc. This can cause a reduction in surface density at these locations, because i) planetesimals there spend less time per orbit at their semi-major axis than the less eccentric planetesimals elsewhere in the disc, and ii) the rate of catastrophic collisions there is enhanced. We use Laplace-Lagrange theory to investigate how the locations, widths and timescales of the secular resonances of a two-planet system depend on the choice of planets, and apply these considerations to the disc of HD 107146, which extends from 30 to 150au with a depletion at around 70au, to identify combinations of planets expected to be able to reproduce such a structure. We perform N-body simulations of some of these systems and post-process the results to include the effect of collisional evolution, finding that it is possible to obtain a HD 107146-like double-ringed structure.

Sergey Yurchenko, Ahmed Al-Refaie and Jonathan Tennyson

University College London

A027

ExoCross: a general program for generating spectra from molecular line lists

We present ExoCross, an open-access Fortran code for generating spectra (emission, absorption) and thermodynamic properties (partition function, specific heat etc.) from molecular line lists. Input is taken in several formats, including ExoMol and HITRAN. ExoCross is efficiently parallelized showing also a high degree of vectorization. It can work with several line profiles such as Doppler, Lorentzian and Voigt and support several broadening schemes. Voigt profiles are handled by several methods allowing fast and accurate simulations. Two of these methods are new. ExoCross is also capable of working with the recently proposed method of *super-lines*: a super-fast method of handling billions of transitions on-the-fly. ExoCross supports calculations of lifetimes, cooling functions, specific heats and other properties. It can be used to convert between different formats, such as HITRAN, ExoMol and Phoenix. It is capable of simulating non-LTE spectra using a simple two-temperature approach. Different electronic, vibronic or vibrational bands can be simulated separately using an efficient filtering scheme based on the quantum numbers.

Sergey Yurchenko, Jonathan Tennyson, Barry Mant, Katy Chubb and ExoMol team

University College London

A026

Exoplanetary Atlas of molecular opacities: ExoMol Gallery

Molecular opacities play a key role for spectral characterization of atmospheres of exoplanets. These data form the input for opacity models for cool stars and brown dwarfs as well as for radiative transport models involving exoplanets. Different observational technics have different requirements on the quality of the spectroscopic data: some atmospheric studies need a complete description of molecular opacities, while other require very precise line positions. The ExoMol project is dedicated to providing molecular line lists for exoplanet and other hot atmospheres. So far, ExoMol has generated line lists for about 30 key molecular species and more than 20 line lists have been collected from other sources. The last update (2017) included line lists for SiH_4, SiH, SH, PO, PS, NO, $^{17}H_2O$ and $^{18}H_2O$. The line lists for C_2, C_2H_2, C_2H_4 and CH_3Cl will be published soon. Here we present an exoplanetary atlas of molecular opacities produced using the ExoMol line lists. Our spectral gallery is aimed at helping to identify prominent atmospheric absorbers based on their key spectral features and to evaluate further molecular data needs.

Tiziano Zingales

University College London

A005

Atmospheric retrieval for 30 gaseous exoplanets

In this work we show the analysis of 30 gaseous extrasolar planetary atmosphere, with temperatures between 600 and 2400 K and radii between 0.35 and 1.9 R_{jup}. We define a new metric, the Atmospheric Detectability Index (ADI) to evaluate the statistical significance of an atmospheric detection and find statistically significant atmospheres around 16 planets. For most of the Jupiters in our sample we find the detectability of their atmospheres to be dependent on the planetary radius but not on the planetary mass. This indicates that planetary gravity is a secondary factor in the evolution of planetary atmospheres. We detect the presence of water vapour in all the statistically detectable atmospheres and we cannot rule out its presence in the atmospheres of the others. In addition, TiO and/or VO signatures are detected with 4σ confidence in WASP-76 b, and they are most likely present on WASP-121 b. We find no correlation between expected signal-to-noise and atmospheric detectability for most targets. This has important implications for future large-scale surveys.