UKEXOM 2016

30^{th} March – 1^{st} April 2016

University of Exeter

Welcome to the third UK Exoplanet Community Meeting taking place at the University of Exeter

Local Organising Committee (green*)

Emma Way
Ben Drummond
Tiffany Kataria
Hannah Wakeford
Tom Evans
Felix Sainsbury-Martinez
Sam Morrell
David Skålid Amundsen
Jayesh Goyal
Elisabeth Matthews
Florian Debras

Scientific Organising Committee (orange*)

Isabelle Baraffe
David Sing
Sasha Hinkley
Nathan Mayne
Didier Queloz
Don Pollacco
Christiane Helling

*LOC and SOC members will be identifiable by the coloured dots on their name badges

Scientific Programme

Wednesday 30th March

09:30 – 10:15	Welcome / Registration / Tea & Coffee
10:15 – 10:25	Introduction I Baraffe
	Session I Detection & statistics
10:30 – 11:05	(Invited) **D Ségransan** (Geneva) *Title: TBC*
11:05 – 11:30	A Triaud (Cambridge, Postdoc) *The many reasons to search for circumbinary planets*
11:30 – 11:55	H Osborn (Warwick, PhD) *Single transit detections in the era of high-precision photometry*
11:55 – 12:10	Tea / Coffee
12:10 – 12:35	S Durkan (Queen's Belfast, PhD) *High constrast imaging with Spitzer: Constraining the frequency of giant planets out to 1000 AU*
12:35 – 13:00	H Celga (Queen's Belfast, Postdoc) *The Rossiter McLaughlin effect reloaded: Convective problems and new solutions*
13:00 – 14:00	Lunch / Posters
14:00 – 14:25	M Bonavita (Edinburgh, Postdoc) *Constraints on the frequency of sub-stellar companions on wide circumbinary orbits*
14:25 – 14:50	S Aigrain (Oxford, Staff) *K2SC: Unleashing the potential of K2 for active stars*
	Session II Atmospheres characterisation: observations
14:50 – 15:25	(Invited) **I Snellen** (Leiden) *A review on characterising exoplanet atmospheres*
15:25 – 15:55	Tea / Coffee
15:55 – 16:20	E Longstaff (Leicester, PhD) *New emission lines in the atmosphere of an irradiated brown dwarf*
16:20 – 16:45	J Kirk (Warwick, PhD) *ULTRACAM transmission spectra of 3 highly inflated hot Jupiters*
16:45 – 17:10	W McLean (Armagh, PhD) *Atmospheric characterisation of gas giants using polarimetry*
17:10 – 17:35	B Demory (Cambridge, Postdoc) *New results about a hot super-Earth*
17:45 – 19:00	**Poster session with wine & cheese, Peter Chalk Centre**
19:30 – 22:00	**Dinner at Holland Hall**

Thursday 31st March

Session II Atmospheres characterisation: observations (cont.)

09:00 – 09:25	J Birkby (Harvard, Postdoc) *New frontiers of high-resolution spectroscopy: Probing the atmospheres of brown dwarfs and reflected light*
09:25 – 09:50	D Sing (Exeter, Staff) *HST hot-Jupiter transmission spectral survey: From clear to cloudy exoplanets*

Session III Models

09:50 – 10:25	(Invited) **M Marley** (NASA) *Directly imaged giant planets: What do we hope to learn?*
10:25 – 10:50	G Lee (St Andrews, PhD) *Atmospheric formation of mineral clouds in 3D radiative-hydrodynamic simulation of HD 189733b*
10:50 – 11:20	Tea / Coffee
11:20 – 11:45	A Barker (Cambridge, Postdoc) *Nonlinear tides in planets and stars*
11:45 – 12:10	S Rugheimer (St Andrews, Postdoc) *Impact of UV on the spectral fingerprints of Earth-like planets orbiting FGKM stars*
12:10 – 12:35	G Vallis (Maths Exeter, Staff) *Idealized 3D modelling of terrestrial exoplanetary atmosphere*
12:35 – 13:00	S Yurckenko (UCL, Staff) *Opacities for modelling atmospheres of exoplanets*
13:00 – 14:00	Lunch / Posters
14:00 – 14:25	N Mayne (Exeter, Staff) *Modelling exoplanet atmospheres: The University of Exeter and the UK Met Office*

Session IV Planet Host Stars

14:25 – 15:00	(Invited) **C Aerts** (Leuven) *Asteroseismology of exoplanet host stars*
15:00 – 15:25	D Staab (OU, PhD) *Chromospheric activity of transiting planet hosts: Mass loss and star planet interactions*
15:25 – 15:50	T Mocnik (Keele, PhD) K2 looks towards WASP-85, WASP-75, WASP-55 and Qatar-2
15:50 – 16:20	Tea / Coffee
16:20 – 16:45	V Rajpaul (Oxford, PhD) *Gaussian processes for modelling stellar activity and detecting planets*

16:45 – 17:10 G Davies (Birmingham, Postdoc)
Gyrochronology: Here be dragons

17:10 – 17:35 R Haywood (Harvard/St Andrews, Postdoc)
Towards precise and accurate exoplanet mass determinations: HARPS-N observes the Sun

17:35 – 18:00 C Watson (Queen's Belfast, Staff)
Towards Earth-analogues: Overcoming convection

18:30 – 19:15 Drinks reception, Holland Hall
19:15 – 23:00 Conference Dinner, Holland Hall

Friday 1st April

Session V Planet Formation

09:00 – 09:35	(Invited) **K Dullemond** (Heidelberg) *Observational signatures of planet formation in discs*
09:35 – 10:00	G Coleman (Queen Mary, PhD) *Forming giant planets in radially structured discs*
10:00 – 10:25	G Laibe (St Andrews, Postdoc) *Clouds above protoplanetary discs*
10:25 – 10:55	Tea / Coffee
10:55 – 11:20	J Teyssandier (Cambridge, Postdoc) *Growth of eccentric modes in disc-planet interactions*
11:20 – 11:45	P Loren-Aguilar (Exeter, Postdoc) *Toroidal vortices as a solution to the dust migration problem*
11:45 – 12:10	P Carter (Bristol, Postdoc) *Compositional evolution of growing terrestrial planet embryos*
12:10 – 12:35	S Matsumura (Dundee, Staff) *Effects of dynamical evolution on compositions of planets*
12:35 – 13:45	Lunch / Poster

Session VI Future Instruments and Perspective

13:45 – 14:20	(Invited) **D Mouillet** (Grenoble) *An overview on new instruments for exoplanet imaging and perspective*
14:20 – 14:55	(Invited) **C Vincent** (STFC) (20 min talk + 15 min questions) *The STFC perspective*
14:55 – 15:20	I Parry (Cambridge, Staff) *SUPERSHARP: A space telescope for direct imaging and spectroscopy of exoplanets*
15:20 – 15:50	Tea / Coffee
15:50 – 16:15	D Queloz (Cambridge, Staff) *Cheops, Tess, Speculoos & Co…*
16:15 – 16:40	G Tinetti (UCL, Staff) *The science of ARIEL*
16:40 – 17:05	S Hinkley (Exeter, Staff) *Spectroscopic characterization of exoplanets at VLT and E-ELT*
17:05 – 17:15	Conclusions / end of meeting

Posters

Detection and Statistics

Name	Title
Joseph Cooper	Planetary Composition from Disintegrating Exoplanets
Maximilian Günther	Identification of False Positives in the Next Generation Transit Survey
Richard Hall	Measuring effective pixel positions for high resolution radial velocity measurements on HARPS3
Kirstin Hay	Stirring up the hornets' nest: three new WASP planets
Kristine Lam	WASP-127b, WASP-136b and WASP-138b: Two new transiting hot Jupiters and a sub-Neptunian mass planet
Elisabeth Matthews	Direct Imaging of Exoplanets and Debris Disks
Eva Plávalová	Classification of extrasolar planets? That is the question.
Benjamin Pope	Planet Candidates from the K2 Mission
John Strachan	Using differing Noise Models for detection of exoplanets from radial velocity measurements
Oliver Turner	Performance of WASP-South using 85mm lenses
Dimitri Veras	Disintegrating minor planets around WD 1145+017 and the implications for planetary science.

Atmosphere Characterisation (observations)

Name	Title
Joanna Barstow	Retrievals of exoplanet atmospheres observed with JWST
Ernst de Mooij	Ground-based search for the atmosphere of 55Cnc e
Thomas Evans	Characterisation of transiting exoplanet atmospheres with HST
Ryan Garland	Optimal Estimation and MCMC with NEMESIS: Brown dwarf atmospheres
Samuel Gill	Wavelet Analysis of CORALIE Spectra
George King	High Energy Environments of Close-in Exoplanets
Thomas Louden	Spatially resolved winds on an exoplanet
Pierre Maxted	ELLC - a fast, flexible light curve model for detached eclipsing binary stars and transiting exoplanets

Hannu Parviainen	Ground-based transmission spectroscopy of WASP-80b
Subhajit Sarkar	ExoSim: A generic simulator of transit spectroscopy observations
Jessica Spake	Clear skies ahead? Characterising exoplanet atmospheres as clear or cloudy with the help of ground-based, K-band photometry
Angelos Tsiaras	An atmosphere around the super-Earth 55 Cnc e
Hannah Wakeford	Marginalizing instrument systematics in HST WFC3 transit light curves
Ingo Waldmann	Dreaming of atmospheres: recognising exoplanet spectra with deep belief networks
Johanna Vos	The First Search for Exoplanet Weather

Modelling (atmosphere, interior structure/evolution)

Name	**Title**
Amy Bonsor	Planetary Compositions derived from White Dwarf Pollution
Benjamin Drummond	Fully Consistent Photochemical Modelling of Exoplanet
Éric Hébrard	Chemical uncertainties in modelling hot Jupiters atmospheres
Christina Hedges	Pressure broadening in exoplanet atmospheres
Gabriella Hodosán	Lightning on exoplanets and brown dwarfs: modelling lightning energies and detecting radio
Mark Hollands	Ancient planetary systems at white dwarfs
Tiffany Kataria	The atmospheric circulation of a nine-hot Jupiter sample: Probing circulation and chemistry over a wide phase space
Stephane Mazevet	Ab initio modelling of planetary interiors
Marco Rocchetto	A next generation retrieval code for exoplanetary atmospheres
Felix Sainsbury-Martinez	Buoyancy Instabilities from Anisotropic Conduction in Stellar and Planetary atmospheres
David Skålid Amundsen	Simulations of HD 209458b using the UK Met Office Global Circulation Model, the Unified Model
Scott Thomas	In hot water: Temperature-dependent models of watery super-Earths
Jack Yates	"Atmospheric Habitable Zones": the Habitability of Cool Brown Dwarf Atmospheres

Planet Host Stars (asteroseismology, stellar activity)

Name	Title
Rachel Booth	An improved stellar age-activity relationship for ages beyond a gigayear
Tiago Campante	Asteroseismology and Exoplanets — IVth Azores International Advanced School in Space Sciences
Jessica Kirkby-Kent	Measuring Binary Parameters for Stellar Model Calibration
Joe Llama	Transiting the Sun
Andrea Miglio	The symbiosis between asteroseismology and exoplanet studies: challenges for the next decade
Charlotte Norris	Preliminary outcomes for 3D facular modelling
Katja Poppenhaeger	Putting a new spin on stellar activity: the tidal effects of Hot Jupiters on their host stars
Andrew Thompson	Determining the Spot Coverage of Exoplanet Host Stars

Planet Formation

Name	Title
Daniel Evans	High-resolution Imaging of Transiting Extrasolar Planetary systems (HITEP)
Mark Fletcher	Novel model for debris discs - planet correlations
Duncan Forgan	Fragmentation in magnetised self-gravitating discs
Edward Gillen	The first low-mass, pre-main sequence eclipsing binary with evidence of a circumbinary disk
Cassandra Hall	Directly observing continuum emission from self-gravitating spiral waves in protostellar discs
Paul Hallam	Investigating the depth of Gaps formed by Planets in Protoplanetary Discs
Stefan Lines	Forming the Kepler circumbinary planets: Is in-situ growth possible?
Alexander Mustill	The effects of dynamics on the multiplicities of Kepler planets
Matthew Mutter	The impact of self-gravity on circumbinary disc and planet evolution
Andrew Shannon	The unseen planets of double belt debris disk systems

Future Instruments and Perspective

Name	Title
Martin Dominik	“GravityCam” – Ground-based wide-field high-resolution imaging and high-speed photometry
James McCormac	NGTS - The Next Generation Transit Survey
Enzo Pascale	The EXoplanet Climate Infrared Telescope (EXCITE)
Don Pollacco	Upcoming Space Experiments
John Young	HARPS3 at the Isaac Newton Telescope: robotic control overview

Session I Detection and Statistics

Name: **Suzanne Aigrain** (Faculty (Permanent Staff))
Affiliation: University of Oxford
Title: K2SC: Unleashing the potential of K2 for active stars (Oral)
Session: Detection and statistics
Abstract: One of the strengths of the K2 mission is its ability to observe nearby young open clusters. However, the enhanced variability of young stars makes it challenging to disentangle instrumental systematics, stellar and planetary signals. I will present K2SC, a new pipeline to model instrumental systematics and astrophysical variability in K2 data, which enables us to recover photometric performance similar to that of the original Kepler mission, even for variable stars. I will compare the output of K2SC to other publicly available K2 pipelines, present transit injection tests, and show how K2SC is being used to find transits, model eclipsing binaries and measure stellar rotation periods in open cluster stars observed by K2. The K2SC code and data from campaigns 3 to 5 are publicly available.

Name: **Isabelle Baraffe** (Faculty (Permanent Staff))
Affiliation: University of Exeter
Title: Introduction (Oral)
Session: Detection and statistics
Abstract: Introduction to the conference/practical information

Name: **Mariangela Bonavita** (Post-Doc)
Affiliation: Institute of Astronomy - University of Edinburgh
Title: Constraints on the frequency of sub-stellar companions on wide circumbinary orbits (Oral)
Session: Detection and statistics
Abstract: A large number of direct imaging surveys for exoplanets have been performed in recent years, yielding the first directly imaged planets and providing constraints on the prevalence and distribution of wide planetary systems. However, like most of the radial velocity ones, these surveys generally focus on single stars, hence binaries and higher-order multiples have not been studied to the same level of scrutiny. This motivated the SPOTS (Search for Planets Orbiting Two Stars) survey, which is an ongoing direct imaging study of a large sample of close binaries, started with VLT/NACO and now continuing with VLT/SPHERE. To complement this survey, we have identified close binary targets in 24 published direct imaging surveys. In this talk I will present the results of our statistical analysis of the resulting sample of 117 tight binary systems, aimed at deriving the expected values of the frequency of companions, for different values of the companion's mass and semi-major axis.

Name: **Heather Cegla** (Post-Doc)
Affiliation: Queen's University Belfast
Title: The Rossiter McLaughlin effect reloaded: Convective Problems and New Solutions (Oral)
Session: Detection and statistics
Abstract: We explore the impact of magnetoconvection on the Rossiter-McLaughlin effect and present a new modelling technique. We start by simulating a hot Jupiter about a Sun-like star for a variety of rotation rates, both with and without convective centre-to-limb variations (in net blueshift and line profile asymmetry). We find that ignoring these convective effects generates residuals that increase with increasing stellar rotation and decreasing intrinsic profile width. Moreover, we show that these effects can introduce systematic errors in the projected obliquities on the order of ~20 degrees, given moderate rotation (e.g. 6 km/s). To avoid such biases, we present a new technique that directly measures the spatially-resolved stellar spectrum behind the planet. We do so by scaling the continuum flux from high precision ground-based spectra by a transit light curve, and subtracting the in- from the out-of-transit spectra to isolate the starlight behind the planet. We then measure the local velocity shifts behind the planet, and model them as a combination of differential stellar rotation and position-dependent convective blueshift. We apply this technique to HD 189733, where we find good agreement with 3D MHD simulations and rule out rigid body rotation with high confidence (>99% probability); this in turn allows us to disentangle the equatorial velocity and stellar inclination. As such, we determine both the sky-projected (-0.4 +/- 0.2 degrees) and true 3D obliquity (7^+12_-4 degrees). Hence, we provide a new powerful tool that can probe

stellar photospheres, differential rotation, determine 3D obliquities, and remove sky projection biases in planet migration theories.

Name: **Joseph Cooper** (PhD Student)
Affiliation: The Open University
Title: Planetary Composition from Disintegrating Exoplanets (Poster)
Session: Detection and statistics
Abstract: Recent publications have shown that extreme cases of hot Jupiters exist, these are so close to the host star that a comet-like tail is formed around the planets orbit. This project uses the SuperWASP archive to look through thousands of suspected planetary transits for those that could be disintegrating. The poster will present the current techniques being used for the search and the initial search results.

Name: **Stephen Durkan** (PhD Student)
Affiliation: Queen's University Belfast
Title: High Contrast Imaging with Spitzer: Constraining the Frequency of Giant Planets out to 1000 AU separations (Oral)
Session: Detection and statistics
Abstract: This contribution highlights the results of a re-analysis of archival Spitzer IRAC direct imaging surveys encompassing a variety of nearby stars. Our sample is generated from the combined observations of 73 young stars (median age, distance, spectral type = 85 Myr, 23.3 pc, G5) and 48 known exoplanet host stars with unconstrained ages (median distance, spectral type = 22.6 pc, G5). For Spitzer, and similar space telescopes, imaging capability has been severely limited by the large PSF associated with the small (0.85m) telescope diameter, leading to a strong preference in con- ducting imaging surveys with AO corrected instruments on 8m class ground based telescopes. The resolution and achievable contrast afforded by such instruments has allowed numerous imaging studies to place robust constraints on the frequency of 0.5 - 13 MJ planets over separations on the order of 10 - 100 AU. However limitations have confined sensitivity to this separation range, leaving the wide giant planet population beyond that poorly constrained. Here we apply sophisticated high-contrast techniques to our sample in order to remove the stellar PSF and open up sensitivity to planetary mass companions down to 5” separations. This enables sensitivity to 0.5 - 13 MJ planets at physical separations on the order of 100 _ 1000 AU , allowing us to probe a parameter space which has not previously been systematically explored to any similar degree of sensitivity. Based on a colour and proper motion analysis we do not record any planetary detections. Exploiting this enhanced survey sensitivity, employing Monte Carlo simulations with a Bayesian approach, and assuming a mass distribution of $dn/dm \propto m^{-1.31}$, we constrain (at 95% confidence) a population of 0.5 - 13 MJ planets at separations of 100 - 1000 AU with an upper frequency limit of 9%.

Name: **Maximilian Günther** (PhD Student)
Affiliation: University of Cambridge
Title: Identification of False Positives in the Next Generation Transit Survey (Poster)
Session: Detection and statistics
Abstract: The Next Generation Transit Survey (NGTS) is a new exoplanet hunter operating at ESO’s Paranal Observatory in Chile. Transit surveys like NGTS are an efficient method of detecting new exoplanets, but are hindered by astrophysical false positives that mimic planet transits, and which outnumber the planet yield by typically two orders of magnitude. We develop tools to automatically identify false positives from NGTS’ photometric data: we use lightcurve features to identify unresolved eclipsing binaries, and implement centroid tracking and pixel-level lightcurve analyses to detect variable background objects blended in the aperture. Here, I will present our methods and results from current NGTS data.

Name: **Richard Hall** (PhD Student)
Affiliation: University of Cambridge
Title: Measuring effective pixel positions for high resolution radial velocity measurements on HARPS3 (Poster)
Session: Detection and statistics
Abstract: We present our work on an optical test bench to measure the effective pixel positions on a CCD for the high resolution (R~100,000) spectrograph HARPS3, which is a new instrument planned for the Isaac Newton Telescope (INT).

In the radial velocity (RV) technique of exoplanet detection, an Earth-mass planet produces a radial velocity signal of amplitude 0.1m/s. On the HARPS3 4k x 4k CCD, this RV measurement equates to a spectroscopic Doppler shift of 1x10^-4pixel. One of the sources of the systematic error in the system is in the calculation of the wavelength solution. Improvements in this wavelength calibration require a better understanding of the effective pixel positions. In this paper we present; our initial experiment design, a description of our optical test bench, the measures we take to minimise environmental noise, and the principle and techniques used to determine the effect pixel sizes and locations to the 1x10-4px limit.

Name: **Kirstin Hay** (PhD Student)
Affiliation: University of St Andrews
Title: Stirring up the hornets' nest: three new WASP planets (Poster)
Session: Detection and statistics
Abstract: We present the discovery of three new transiting giant planets, first detected by the SuperWASP telescopes, and confirmed with follow up spectroscopy and ground-based photometric lightcurves. All three planets orbit a hot host star of spectral types F4-F7, and have orbital periods of 2.2-4.0 days. The planets are moderately inflated with planetary radii of 1.4-1.6 RJ. They are bright targets (10.9<V<13.2) ideal for further characterisation work, particularly WASP-118b, which is being observed by K2 as part of campaign 8.

Name: **Kristine Wai Fun Lam** (PhD Student)
Affiliation: University of Warwick
Title: WASP-127b, WASP-136b and WASP-138b: Two new transiting hot Jupiters and a sub-Neptunian mass planet (Poster)
Session: Detection and statistics
Abstract: We report three newly discovered planets from the SuperWASP survey. WASP-136b and WASP-138b are both hot Jupiters with mass and radii of 1.50 Mj and 1.27 Rj, 1.23 Mj and 1.00 Rj respectively. WASP-136b orbits a F9 star every 5.22 days and WASP-138b orbits a F7 star with a period of 3.63 days. Their metalicities of [Fe/H] are between -0.18 and -0.09. WASP-127b is a heavily inflated sub-neptunian mass planet of mass 0.13 Mj and radius 1.35 Rj. This is one of the lowest mass planet discovered by the SuperWASP survey. It orbits a host star of spectral type G5 with a period of 4.17 days. The brightness of the star is V=10.16 magnitudes which makes this low density planet an ideal candidate for follow up atmospheric studies. The discoveries of these new planets will help understanding the physical characteristics of hot Jupiters and sub-Neptunian planets.

Name: **Elisabeth Matthews** (PhD Student)
Affiliation: University of Exeter
Title: Direct Imaging of Exoplanets and Debris Disks (Poster)
Session: Detection and statistics
Abstract: In the last 20 years, ~1500 exoplanets have been discovered indirectly, and the majority of these lie within ~5AU of their host stars. The direct imaging of exoplanets is the only technique which allows young planets at the widest separations to be discovered, but as yet only a handful of exoplanets of this type have been identified. Further to this, the direct imaging technique is the only one that allows direct spectroscopy of exoplanets, making it a powerful technique for constraining the formation and early evolution of exoplanets.

The newly operational SPHERE and GPI instruments, on the Very Large and Gemini Telescopes respectively, are the first instruments designed specifically with direct imaging in mind, and are already proving their superiority over previous facilities (e.g. with the discovery of 51 Eri b, Macintosh et. al. 2015). In this talk I will discuss the importance of debris dust in the detection and characterisation of exoplanetary candidates, and then present initial results from our SPHERE survey of young, debris-belt hosting stars.

Name: **Hugh Osborn** (PhD Student)
Affiliation: University of Warwick
Title: Single Transit detections in the era of high-precision photometry (Oral)
Session: Detection and statistics
Abstract: Modern photometric transit surveys such as Kepler, TESS, NGTS and PLATO now have the precision to identify exoplanets from only a single transit. This will allow the detection and validation of planets down to super-Earth radii on periods longer than traditionally possible. Provided the host star can be characterised, the information contained within a single transit can also be used to estimate a circular orbital period, which can be

demonstrated using known Kepler planets.

I will present the results of a search for single transits in the first six K2 fields which now include more than a dozen potential planet candidates including EPIC203311200, a likely exoplanet with period of 540 +410/-230 days and a radius of 0.51+/-0.05 Rjup. I will also provide orbital period and radii estimates for the remaining objects and detail results from an ongoing follow-up campaign.

Finally, I will address the capability of future transit surveys such as TESS & NGTS to detect & analyse single transits, and show that the asteroseismological capability of PLATO will make it an exceptional tool for single transits.

Name: **Eva Plávalová** (Post-Doc)
Affiliation: Astronomical Institute of the Slovak Academy of Sciences, Interplanetary Matter
Title: Classification of extrasolar planets? That is the question. (Poster)
Session: Detection and statistics
Abstract: Spectral classification of stars is now common and widely used. Every day, new planet-candidates are being discovered and with the volume of planets expected to dramatically accelerate, without a good system of classification in place, the backlog of planets waiting to be analysed would slow down research. We can discuss how this classification (taxonomy) should look like.

Name: **Benjamin Pope** (PhD Student)
Affiliation: University of Oxford
Title: Planet Candidates from the K2 Mission (Poster)
Session: Detection and statistics
Abstract: I will present the results of a search for transiting planet candidates in Kepler-2 (K2), and in particular Campaign 5, using the Gaussian Process-based 'K2SC' algorithm (Aigrain et al. 2016) to correct for the K2 pointing systematics. This method is designed specifically to detect planets around active or variable stars. In this talk, I will discuss the methods used and the planet candidates we have detected, as well as the results of spectroscopic follow-up for several of these candidates, including mass determination. The results for Campaign 5 include a multiply-transiting system, a hot Jupiter and several Neptune-sized planets.

Name: **Didier Queloz** (Faculty (Permanent Staff))
Affiliation: University of Cambridge
Title: Speculoos, finding small planet orbiting small stars (Oral)
Session: Detection and statistics
Abstract: TBD

Name: **Damien Ségransan** (Faculty (Permanent Staff))
Affiliation: Astronomy Dpt., University of Geneva
Title: TBD (Oral)
Session: Detection and statistics
Abstract: TBD

Name: **John Strachan** (PhD Student)
Affiliation: Queen Mary University of London
Title: Using differing Noise Models for detection of exoplanets from radial velocity measurements (Poster)
Session: Detection and statistics
Abstract: Using a Bayesian framework and Markov Chain Monte Carlo we analyse the radial velocity measurements for GJ667C and take account of noise (both uncorrelated and correlated) in our models. We perform the analyses on simulated multiplanet systems (GJ 667C and Kepler 11) and real data sets to assess the impact of different models in exoplanet detection sensitivities. We argue that better models and observables are needed to better establish the activity Doppler relations. Exploitation of new spectroscopic observables in the red and nIR part of the stellar spectrum using CARMENES will be explored in the near future.

Name: **Amaury Triaud** (Post-Doc)
Affiliation: Institute of Astronomy, University of Cambridge
Title: The many reasons to search for circumbinary planets (Oral)
Session: Detection and statistics
Abstract: Circumbinary planets offer many opportunities. Their properties challenge established ideas about how close binary stars are formed; they also expand our understanding about how planets are assembled and how their orbits subsequently evolve. In addition, the nature of their geometry and orbital dynamics renders the probability of planetary transits independent of orbital distance and 95% assured for eclipsing binary systems. This greatly facilitates the eventual characterisation of the atmospheres of long-period gas giants while they transit. After describing these properties and their usage, I will outline a new survey whose aim is to discover planets using the radial velocity method, before finding when those come into transit.

Name: **Oliver Turner** (PhD Student)
Affiliation: Keele University
Title: Performance of WASP-South using 85mm lenses (Poster)
Session: Detection and statistics
Abstract: We have recently completed a three year survey of the southern sky using a modified WASP-South instrument. In 2012 the instrument switched from using 200mm lenses to 85mm lenses to gather data on brighter stars. The goal is to find hot-Jupiters orbiting bright host stars, analogous to the extensively-studied systems HD 209458 b and HD 189733 b. Targets like these are particularly valuable because they are bright enough for very detailed follow up observations with VLT, E-ELT, JWST, etc. Here we present the performance of our updated WASP data reduction pipeline, quantify the detection efficiency of the modified instrument and evaluate the degree to which blending may affect the results.

Name: **Dimitri Veras** (Post-Doc)
Affiliation: University of Warwick
Title: Disintegrating minor planets around WD 1145+017 and the implications for planetary science (Poster)
Session: Detection and statistics
Abstract: A major development since the last UK Exoplanet Community Meeting was the October 2015 Nature result demonstrating that transit photometry reveals multiple planetesimals currently disintegrating around the polluted and disc-bearing white dwarf WD 1145+017 (Vanderburg et al. 2015, Nature, 526, 546). The UK is a dominant player in post-main-sequence planetary science, and a group of us from Warwick, Sheffield, UCL, Leicester and Bristol have performed high-speed observations of this system and created theoretical models to explain it. I will present the results, which illustrate [1] multiple transit events in every light curve, with varying durations (~3-12min) and depths (~10-60%), [2] transit evolution on timescales of days, both in shape and in depth, and [3] recurring transits over multiple nights on periods of ~4.49h, indicating multiple planetary debris fragments on nearly identical near-circular orbits. I will also exhibit the constraints that we have obtained on the physical properties of the disintegrating objects by performing tidal disruption simulations with PKDGRAV and N-body simulations with MERCURY.

Session II Atmosphere Characterisation (observations)

Name: **Joanna Barstow** (Post-Doc)
Affiliation: University of Oxford
Title: Retrievals of exoplanet atmospheres observed with JWST (Poster)
Session: Atmosphere characterisation (observations)
Abstract: The James Webb Space Telescope, due to launch in 2018, will transform our ability to observe transiting exoplanet atmospheres. The large primary mirror will improve the precision of transit spectra, and the extensive infrared wavelength coverage will enable us to better break degeneracies between molecular absorption features, temperature structure and clouds. I will discuss the feasibility of detailed atmospheric characterisation with JWST, particularly focusing on the issue of astrophysical systematic noise.

Name: **Jayne Birkby** (Post-Doc)
Affiliation: Harvard-Smithsonian Center for Astrophysics
Title: New frontiers of high-resolution spectroscopy: Probing the atmospheres of brown dwarfs and reflected light from exoplanets (Oral)
Session: Atmosphere characterisation (observations)
Abstract: High-resolution spectroscopy (R>25,000) is a robust and powerful tool in the near-infrared characterization of exoplanet atmospheres. It has unambiguously revealed the presence of carbon monoxide and water in several hot Jupiters, measured the rotation rate of beta Pic b, and suggested the presence of fast day-to-night winds in one atmosphere. The method is applicable to transiting, non-transiting, and directly-imaged planets. It works by resolving broad molecular bands in the planetary spectrum into a dense, unique forest of individual lines and tracing them directly by their Doppler shift, while the star and tellurics remain essentially stationary. I will focus on two ongoing efforts to expand this technique. First, I will present new results on 51 Peg b revealing its infrared atmospheric compositional properties, then I will discuss an ongoing optical HARPS-N/TNG campaign to obtain a detailed albedo spectrum of 51 Peg b at 387-691 nm in bins of 50nm. This spectrum would provide strong constraints on the previously claimed high albedo and potentially cloudy nature of this planet. Second, I will discuss preliminary results from Keck/NIRSPAO observations of LHS 6343 C, a 1000 K transiting brown dwarf with an M-dwarf host star. The high-resolution method converts this system into an eclipsing, double-lined spectroscopic binary, thus allowing dynamical mass and radius estimates of the components, free from astrophysical assumptions. Alongside probing the atmospheric composition of the brown dwarf, these data would provide the first model-independent study of the bulk properties of an old brown dwarf, with masses accurate to <5%, placing a crucial constraint on brown dwarf evolution models.

Name: **Ernst de Mooij** (Post-Doc)
Affiliation: Queen's University Belfast
Title: Ground-based search for the atmosphere of 55Cnc e (Poster)
Session: Atmosphere characterisation (observations)
Abstract: At V=5.95, the star 55Cnc is currently one of the brightest stars in the sky known to host a transiting planet, the super-Earth 55Cnc e. This super-Earth has a density lower than that of the Earth and could potentially have either a significant water fraction or a hydrogen-rich envelope, although a hydrogen-rich envelope could have evaporated. I will present high-cadence differential spectrophotometric transit observations of this planet, which constitute the first ground-based detection of the transit of 55Cnc e. I will also present the results follow-up observations at high spectral resolution aimed at detecting water in the planet's atmosphere.

Name: **Brice-Olivier Demory** (Post-Doc)
Affiliation: University of Cambridge
Title: New results about a hot super-Earth (Oral)
Session: Atmosphere characterisation (observations)
Abstract: [Under embargo] I will present new results obtained with the Spitzer Space Telescope about the super-Earth 55 Cancri e.

Name: **Thomas Evans** (Post-Doc)
Affiliation: University of Exeter
Title: Characterisation of transiting exoplanet atmospheres with HST (Poster)
Session: Atmosphere characterisation (observations)
Abstract: I will present new transmission spectroscopy results obtained with HST for two planets. The first is HAT-P-18, a warm-Saturn with an equilibrium temperature of 850K, which is cool enough for equilibrium models to predict an abundance of methane absorption. The second is WASP-121b, an ultra-hot gas giant orbiting just beyond the Roche limit, possibly undergoing tidal disruption.

Name: **Ryan Garland** (PhD Student)
Affiliation: University of Oxford
Title: Optimal Estimation and MCMC with NEMESIS: Brown dwarf atmospheres (Poster)
Session: Atmosphere characterisation (observations)
Abstract: Brown dwarfs are a key test-bed for extrasolar giant planet (EGP) models because of their similar atmospheric temperature ranges and composition to EGPs and high-resolution spectra. To understand the extent to which we can reliably retrieve atmospheric parameters and solve the inverse problem, we employ two different Bayesian techniques, Optimal Estimation (OE) and Markov Chain Monte Carlo (MCMC), using our retrieval code NEMESIS. Here we present our preliminary results. First we use a disc-integrated spectrum of Jupiter to verify our methods. We then perform retrievals on two benchmark late T-dwarfs, Gl570 D and HD 3651B, and compare to previously published results.

Name: **Samuel Gill** (PhD Student)
Affiliation: Keele Unversity
Title: Wavelet Analysis of CORALIE Spectra (Poster)
Session: Atmosphere characterisation (observations)
Abstract: We require good constraints on the properties of planet host stars to estimate a planets mass and radius. Comparing transit photometric data and evolutionary models with good host star measurements allows a planets mass and size to be estimated with good accuracy. Measuring rotation and atmospheric parameters (Teff, Log g, [Fe/H], V.sin(i)) of F, G & K host stars can be problematic for spectra of low signal-to-noise due constraints during normalisation. Wavelets provide scale and location information of spectral lines easing the importance of continuum fitting during processing. We will describe an automated analysis pipeline that uses wavelets to compare generated spectra to CORALIE spectra. We test our method on WASP planet host stars for which good atmospheric parameters are available from the detailed analysis of HARPS spectra.

Name: **George King** (PhD Student)
Affiliation: University of Warwick
Title: High Energy Environments of Close-in Exoplanets (Poster)
Session: Atmosphere characterisation (observations)
Abstract: Measuring the x-ray flux from planetary host stars allows us to estimate mass loss from close-in planets. We present ongoing investigations into such star-planet interactions in a variety of systems from Jupiter-size down to super-Earth, using data from the XMM Newton satellite.

Name: **James Kirk** (PhD Student)
Affiliation: University of Warwick
Title: ULTRACAM transmission spectra of 3 highly inflated hot Jupiters (Oral)
Session: Atmosphere characterisation (observations)
Abstract: Transiting hot Jupiters offer an excellent opportunity for the ground based characterisation of exoplanet atmospheres through transmission spectroscopy. The number of hot Jupiters with detected atmospheres is growing and has revealed an interesting diversity of atmospheric compositions. Determining which opacity sources dominate in different physical conditions is critical to understanding the chemistry of highly irradiated planetary atmospheres. I will present ULTRACAM transmission spectra of three highly inflated hot Jupiters with error bars of approximately one atmospheric scale height, comparable to the precision from HST. This study has resulted in the detection of Rayleigh scattering in two planetary atmospheres, including that of HAT-P-1b which is consistent with HST results, and a featureless transmission spectrum consistent with a cloudy atmosphere.

Name: **Emma Longstaff** (PhD Student)
Affiliation: University of Leicester
Title: New emission lines in the atmosphere of an irradiated brown dwarf (Oral)
Session: Atmosphere characterisation (observations)
Abstract: Brown dwarfs form like stars through core collapse but never achieve the mass necessary for hydrogen fusion. Due to this brown dwarf atmospheres more closely resemble gas giant planets however, they are typically brighter than exoplanets and can be directly observed at wavelengths longwards of 1.2 μm. The atmospheres of brown dwarfs have been very well characterised and their associated models are thus more advanced than their exoplanet counterparts. Brown dwarfs can be regarded as templates for exoplanets and allow for a better understanding of the properties of irradiated atmospheres as a whole. WD0137-349 is one of only five confirmed post common envelope white dwarf -- brown dwarf binary systems and the brown dwarf, in this case, is thought to be tidally locked to its host. Using radial velocity measurements we have found that the brown dwarf has a mass of 57 ± 5 Mjup. We have also discovered the presence of calcium, potassium, sodium, and magnesium in emission. The radial velocities of these lines indicate they originate from the brown dwarf but hint that they are not necessarily from the same region within its atmosphere as the Hα emission.

Name: **Thomas Louden** (PhD Student)
Affiliation: University of Warwick
Title: Spatially resolved winds on an exoplanet (Poster)
Session: Atmosphere characterisation (observations)
Abstract: We will present evidence that the atmosphere of the hot Jupiter HD 189733b has a strong eastward motion, with red-shifted absorption detected on the leading limb of the planet and blue-shifted absorption on the trailing limb. Our results are based on a time-resolved model of the sodium transmission spectrum measured with the HARPS spectrograph. The model includes limb darkening and stellar rotation, and it accounts implicitly for the Rossiter-McLaughlin effect. Our results can be understood as a combination of tidally locked planetary rotation and an eastward equatorial jet. The equatorial jet has long been predicted in atmospheric circulation models, and it helps to explain Spitzer maps of the dayside thermal emission of HD 189733b that show the hottest point of the planetary atmosphere offset to the east of the substellar point. In addition to testing atmospheric circulation models, our results demonstrate the feasibility of studying weather systems on distant planets.

Name: **Dr Pierre Maxted** (Faculty (Permanent Staff))
Affiliation: Keele University
Title: ELLC - a fast, flexible light curve model for detached eclipsing binary stars and transiting exoplanets. (Poster)
Session: Atmosphere characterisation (observations)
Abstract: Very high quality light curves are now available for thousands of detached eclipsing binary stars and transiting exoplanet systems as a result of surveys for transiting exoplanets and other large-scale photometric surveys. I have developed a binary star model (ellc) that can be used to analyse the light curves of these systems that is fast and accurate, and that can include the effects of star spots, Doppler boosting and light-travel time in eccentric orbits. The model represents the stars as triaxial ellipsoids. The apparent flux from the binary is calculated using Gauss-Legendre integration over the ellipses that are the projection of these ellipsoids on the sky. The model can also be used to calculate the flux- weighted radial velocity of the stars during an eclipse (Rossiter-McLaghlin effect). The main features of the model have tested by comparison to observed data and other light curve models. The model is found to be accurate enough to analyse the very high quality photometry that is now available from space- spaced instruments, flexible enough to model a wide range of eclipsing binary stars and extrasolar planetary systems, and fast enough to enable the use of modern Monte Carlo methods for data analysis and model testing.

Name: **Will McLean** (PhD Student)
Affiliation: Armagh Observatory
Title: Atmospheric characterisation of gas giants using polarimetry (Oral)
Session: Atmosphere characterisation (observations)
Abstract: Disk integrated light from solar type stars is virtually unpolarised. This offers a means with which to disentangle the signal of an exoplanet from its parent star, since any polarised signature would be due to the interaction with the planet. Polarimetry is a powerful remote sensing tool for probing the structure and composition of a planetary atmosphere and surface. A famous example of the use of polarimetry in atmospheric characterisation is the study of the clouds of Venus by Hansen & Hovenier (1974), who successfully constrained

the properties of the Venusian clouds through fitting theoretical models to polarimetric observations at various phase angles. In this talk we present some recent results from polarimetric studies of Jupiter and Saturn, and present our modelling of the data, using an adding-doubling radiative transfer code, that fully incorporates multiple scattering and polarisation. Our polarimetric studies of solar system planets could be used to interpret future observations of extrasolar gas giants, and infer details such as particle type, optical thickness, and cloud heights in the atmosphere.

Name: **Hannu Parviainen** (Post-Doc)
Affiliation: University of Oxford
Title: Ground-based transmission spectroscopy of WASP-80b (Poster)
Session: Atmosphere characterisation (observations)
Abstract: We present the results of our transmission spectroscopy analysis of WASP-80b, a warm Jupiter orbiting a bright M-dwarf (spectral type between K7V-M0V). The analysis combines a spectroscopic time series observed with the 10.4 metre Gran Telescopio CANARIAS (GTC) with three sets of previously published ground-based broadband transit light curves (28 in total) into a joint model where all the narrow-band light curves and the broadband light curves modelled simultaneously.

Name: **Subhajit Sarkar** (PhD Student)
Affiliation: Cardiff University School of Physics and Astronomy
Title: ExoSim: A generic simulator of transit spectroscopy observations (Poster)
Session: Atmosphere characterisation (observations)
Abstract: The technique of transit spectroscopy has in recent years yielded a number of emergent spectra in both primary transit and secondary eclipse. These observations have been performed from both ground-based and space-based telescopes. Due to the very small contrast ratios involved such observations and the spectra after data reduction are highly sensitive to noise from both astrophysical and instrument sources as well as systematics. Determining the uncertainties on the final spectrum can be challenging using purely analytical means, due to the complex interactions between multiple noise sources, the effects of non-gaussian or correlated noise and the effects of instrumental and systematic noise. Stellar variations can add an additional layer of uncertainty. The noise from the effects of pointing jitter is highly complex and in the spectral domain might not be amenable to analytical prediction. To address this we have developed a numerical modular software package called ExoSim that simulates a complete end-to-end transit spectroscopy observation, and can be applied easily to different instrument designs, including both space- or ground-based telescopes. Using such software we can perform simulations to determine how the multiple noise sources combine to produce the final uncertainties on an observation and on the final spectrum, including through Monte Carlo simulations. ExoSim has been used to determine the noise characteristics for the Ariel telescope, an ESA M4 candidate mission. It will also be used in the planning of the Ariel mission level observational strategy. It has the capability of simulating scanning mode (used on the Hubble WFC3), allowing us to assess the uncertainties associated with this mode. We are in the process of incorporating a stellar variability function. ExoSim is the first generically-applicable numerical simulator of transit spectroscopy that can be easily applied to any instrument that works in this mode. ExoSim will also soon be made open-access.

Name: **David Sing** (Faculty (Permanent Staff))
Affiliation: University of Exeter
Title: HST hot-Jupiter transmission spectral survey: from clear to cloudy exoplanets (Oral)
Session: Atmosphere characterisation (observations)
Abstract: The large number of transiting exoplanets has prompted a new era of atmospheric studies, with comparative exoplanetology now possible. Here we present the comprehensive results from a Large program with the Hubble Space Telescope, which has recently obtained optical and near-IR transmission spectra for eight hot-Jupiter exoplanets in conjunction with warm Spitzer transit photometry. The spectra show a wide range of spectral behavior, which indicates diverse cloud and haze properties in their atmospheres. I will discuss the overall findings from the survey, comment on common trends observed in the exoplanet spectra, and remark on their theoretical implications.

Name: **Ignas Snellen** (Faculty (Permanent Staff))
Affiliation: Leiden Observatory
Title: A review on characterising exoplanet atmospheres (Oral)
Session: Atmosphere characterisation (observations)
Abstract: TBD

Name: **Jessica Spake** (PhD Student)
Affiliation: University of Exeter
Title: Clear skies ahead? Characterising exoplanet atmospheres as clear or cloudy with the help of ground-based, K-band photometry (Poster)
Session: Atmosphere characterisation (observations)
Abstract: An essential part of understanding exoplanet atmospheres is measuring their abundances of important molecules like water and carbon dioxide. This can be done via transmission spectroscopy. When a planet passes in front of its star, its wavelength-dependent apparent size can tell us about which atmospheric molecules are absorbing the incoming starlight. However, high-altitude clouds in an exoplanet atmosphere can mask the signatures of this molecular absorption. It is therefore useful to know if an exoplanet is clear or cloudy before many hours of expensive, space-based telescope time are spent characterising its atmosphere. I will discuss a new metric for characterising an atmosphere as clear or cloudy with the help of ground-based, K-band photometry. This is similar to the metrics developed by Sing et al. (2016). I will also present the results of this metric applied to new data for several planets.

Name: **Angelos Tsiaras** (PhD Student)
Affiliation: UCL
Title: An atmosphere around the super-Earth 55 Cnc e (Poster)
Session: Atmosphere characterisation (observations)
Abstract: One of the most successful instruments for observing exoplanetary atmospheres is the Wide Field Camera 3 (WFC3) onboard the Hubble Space Telescope (HST). In particular, the use of the spatial scanning technique has given us the opportunity for even more efficient observations of the brightest targets, achieving the necessary precision of 10-100 PPM. With such data and new advanced reduction and statistical techniques, we were able to detect modulations in the spectrum of the hot super-Earth 55 Cancri e, which suggest the existence of a light-weight atmosphere around this planet. In this talk, I will review the current WFC3 observations and data analysis techniques used to probe the atmospheres of known extrasolar planets. I will also discuss the limits of current observatories and the next steps that arguably need to be taken to progress in this fascinating new field.

Name: **Johanna Vos** (PhD Student)
Affiliation: University of Edinburgh
Title: The First Search for Exoplanet Weather (Poster)
Session: Atmosphere characterisation (observations)
Abstract: Periodic variability due to rotation and patchy cloud cover has been detected in L and T brown dwarfs, with considerably higher variability amplitudes observed at the L/T transition. Directly imaged planets occupy the same temperature regime as L and T type brown dwarfs and are likely to exhibit similar variability. We are currently conducting the first survey of weather patterns on free-floating young planetary mass objects with NTT SOFI. We aim to discover and characterise variability in these objects and to constrain the fraction that show periodic variability due to rotationally modulated patchy cloud cover. A comparison of our survey with surveys of field brown dwarfs will provide insight into the effects of surface gravity on cloud structure. Here I will present some preliminary results from this survey.

Name: **Hannah Wakeford** (Post-Doc)
Affiliation: NASA Goddard Space Flight Center
Title: Marginalizing instrument systematics in HST WFC3 transit lightcurves (Poster)
Session: Atmosphere characterisation (observations)
Abstract: We present the application of marginalisation based on Gibson (2014) to analyse exoplanet transit lightcurves obtained from HST WFC3, to better determine important transit parameters such as Rp/R*, important for accurate detections of H2O. We approximate the evidence, often referred to as the marginal likelihood, for a grid of systematic models using the Akaike Information Criterion (AIC). We then calculate the evidence-based weight assigned to each systematic model and use the information from all tested models to calculate the final

marginalised transit parameters for both the band-integrated, and spectroscopic light curves to construct the transmission spectrum. For WFC3 observations, we find that a majority of the highest weight models contain a correction for a linear trend in time, as well as corrections related to HST orbital phase. We additionally test the dependence on the shift in spectral wavelength position over the course of the observations and find that spectroscopic wavelength shifts $\delta\lambda(\lambda)$, best describe the associated systematic in the spectroscopic lightcurves for most targets, while fast scan rate observations of bright targets require an additional level of processing to produce a robust transmission spectrum. The use of marginalisation allows for transparent interpretation and understanding of the instrument and the impact of each systematic evaluated statistically for each dataset, expanding the ability to make true and comprehensive comparisons between exoplanet atmospheres.

(Work done in collaboration with D.K.Sing, T.Evans, D.Deming and A.Mandell)

Name: **Ingo Waldmann** (Post-Doc)
Affiliation: UCL
Title: Dreaming of atmospheres: recognising exoplanet spectra with deep belief networks (Poster)
Session: Atmosphere characterisation (observations)
Abstract: Here we introduce the RobERt (Robotic Exoplanet Recognition) algorithm for the classification of exoplanetary emission spectra. Spectral retrievals of exoplanetary atmospheres frequently requires the preselection of molecular/atomic opacities to be defined by the user. In the era of open-source, automated and self-sufficient retrieval algorithms, manual input should be avoided. User dependent input could, in worst case scenarios, lead to incomplete models and biases in the retrieval. The RobERt algorithm is based on deep belief neural (DBN) networks trained to accurately recognise molecular signatures for a wide range of planets, atmospheric thermal profiles and compositions. Reconstructions of the learned features, also referred to as `dreams' of the network, indicate good convergence and an accurate representation of molecular features in the DBN. Using these deep neural networks, we work towards retrieval algorithms that themselves understand the nature of the observed spectra, are able to learn from current and past data and make sensible qualitative preselections of atmospheric opacities to be used for the quantitative stage of the retrieval process.

Session III Modelling (atmosphere, interior structure/evolution)

Name: **Adrian Barker** (Post-Doc)
Affiliation: University of Cambridge
Title: Nonlinear tides in planets and stars (Oral)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Tidal interactions between short-period planets and their host stars are thought to play an important role in the evolution of the planetary orbit as well as the stellar and planetary spins. However, the mechanisms responsible for tidal dissipation are not well understood theoretically. I will present new results from a set of global hydrodynamical simulations to study nonlinear tidal flows in short-period gaseous planets from first principles. I will discuss the outcome of the elliptical instability, and the resulting implications for the circularisation, spin-orbit synchronisation and spin-orbit alignment of short-period planets. I will also present results from a set of local ("small-patch") magnetohydrodynamical simulations designed to study the turbulent damping of spin precession in gaseous planets (and stars). This mechanism could play a role in damping the spin-orbit misalignments of planets (and stars).

Name: **Amy Bonsor** (Post-Doc)
Affiliation: Institute of Astronomy, University of Cambridge
Title: Planetary Compositions derived from White Dwarf Pollution (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Composition is key to determining the structure of exoplanets. Yet, using observations of planet mass and radii to determine planet composition suffers from large degeneracies. The best compositions for planetary material outside our Solar System come from observations of white dwarf pollution. Detailed compositions of planetary building blocks accreted onto the white dwarf atmosphere can be derived from spectra.
In this talk, I will compare and contrast the compositions derived from white dwarf pollution with those of terrestrial exoplanets, derived from mass/radii observations. This comparison tells us about the diversity of exoplanets, and highlights potential differences in planetary systems as a function of stellar mass. I will discuss how the observed pollution arrives into the white dwarf atmosphere. Can wide binary companions lead to pollution? What can the observations of dusty discs around polluted white dwarfs tell us about the accretion mechanisms?

Name: **Benjamin Drummond** (PhD Student)
Affiliation: University of Exeter
Title: Fully Consistent Photochemical Modelling of Exoplanet Atmospheres (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: I will present new results from a study of non-equilibrium chemistry in exoplanet atmospheres under conditions relevant to a wide range of planetary types (hot Jupiters to ice giants). I will show that non-equilibrium chemistry can affect the temperature structure of hot Jupiter atmospheres with a large impact on the nightside (a few hundred Kelvin) but a much smaller effect on the dayside. This highlights the need to use both 1D and 3D models together, in a complimentary manner, to study these asymmetric planets. We have developed a 1D radiative-convective atmosphere model, coupling consistently hydrostatic equilibrium, radiative transfer and chemistry. I will also briefly discuss our current developments, the implementation of our non-equilibrium chemistry code in the Met Office UM, a sophisticated general circulation model (GCM). Previous studies either assume chemical equilibrium or do not allow non-equilibrium chemistry to feedback on to the background atmosphere, and none so far have included true chemical kinetics in a 3D GCM.

Name: **Éric Hébrard** (Post-Doc)
Affiliation: NASA Goddard Space Flight Center
Title: Chemical uncertainties in modelling hot Jupiters atmospheres (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Most predictions and interpretations of observations in beyond our Solar System have occurred through the use of 1D photo-thermo-chemical models. Their predicted atmospheric compositions are highly dependent on model parameters. Chemical reactions are based on empirical parameters that must be known at temperatures ranging from 100 K to above 2500 K and at pressures from millibars to hundreds of bars. Obtained from experiments, calculations and educated-guessed estimations, these parameters are always evaluated with

substantial uncertainties. However, although of practical use, few models of exoplanetary atmospheres have considered these underlying chemical uncertainties and their consequences. Recent progress has been made recently that allow us to (1) evaluate the accuracy and precision of 1D models of planetary atmospheres, with quantifiable uncertainties on their predictions for the atmospheric composition and associated spectral features, (2) identify the ‘key parameters’ that contribute the most to the models predictivity and should therefore require further experimental or theoretical analysis, (3) reduce and optimize complex chemical networks for their inclusion in multidimensional atmospheric models.

First, a global sampling approach based on low discrepancy sequences has been applied in order to propose error bars on simulations of the atmospheres HD 209458b and HD 189733b, using a detailed kinetic model derived from applied combustion models that was methodically validated over a range of temperatures and pressures typical for these hot Jupiters. A two-parameters temperature-dependent uncertainty factor has been assigned to each considered rate constant. Second, a global sensitivity approach based on high dimensional model representations (HDMR) has been applied in order to identify those reactions which make the largest contributions to the overall uncertainty of the simulated results. The HDMR analysis has been restricted to the most important reactions based on a non-linear screening method, using Spearman Rank Correlation Coefficients at different level of the modelled atmospheres. The individual contributions of some key reactions, as highlighted by this analysis, will be discussed.

Name: **Christina Hedges** (PhD Student)
Affiliation: Institute of Astronomy, University of Cambridge
Title: Pressure broadening in exoplanet atmospheres (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Spectroscopic observations of exoplanets are leading to unprecedented constraints on their atmospheric chemical compositions. Molecular abundances can be derived from atmospheric spectra using sophisticated models and retrieval methods. However, these are degenerate with molecular absorption cross-sections, crucial inputs to atmospheric models. It is imperative to quantify the uncertainties in molecular cross-sections to reliably estimate the uncertainties in derived molecular abundances for observed exoplanet atmospheres. New, high-temperature molecular transition line lists are now available and we are in a position to investigate molecular cross-sections. In this study we investigate and quantify the effect of pressure broadening on molecular absorption cross-sections, one of the many broadening mechanisms expected to affect observations of exoplanet atmospheres. Our investigation spans a range of different pressures, temperatures, spectral resolutions, molecules and, where possible, broadening agents. We find that the effect of pressure broadening on molecular absorption cross-sections can be significant, over 100%, for high spectral resolutions that can be obtained by present and upcoming instruments, and especially for low temperature atmospheres. This leads to a necessary discussion of our future needs in terms of molecule coverage and pressure broadening data and how this particularly impacts our ability to characterize smaller planets with more complex atmospheres.

Name: **Gabriella Hodosán** (PhD Student)
Affiliation: University of St Andrews
Title: Lightning on exoplanets and brown dwarfs: modelling lightning energies and detecting radio signatures (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Large-scale electrostatic discharges (i.e. lightning) have been observed in the Solar System. Observations also indicate that clouds form on extrasolar planets and brown dwarfs, where the physical conditions may be appropriate for lightning to occur. Lightning may be one of the main ionization processes in these atmospheres: for example, lightning in mineral clouds (e.g., Bailey et al. 2014, ApJ, 784, 43; Helling at al. 2013, ApJ, 767, 136; Helling et al. 2013, P&SS, 77, 152).

The aim of this ongoing study is to apply our knowledge of lightning production, derived mostly from Earth lightning, to the potential discharge characteristics on extrasolar objects. In terms of observations, the power spectrum of lightning carries information regarding radiated power densities. However, modelling the power spectrum involves several steps and various parameters, including a characterization of the large electric field, which leads to the acceleration of electrons to high energies and, eventually, the discharge process. As such, we conducted a parameter study in order to explore the possible lightning powers and energies in different types of extrasolar atmospheres, such as Jupiter-like giant planet atmospheres mostly composed of H/He layers, rocky planets with, e.g., water-rich clouds, or in dust clouds of brown dwarfs.

Most of the energy released from lightning goes into producing optical and radio photons. We focused on the radio signatures of lightning in the high frequency (few MHz ~ few hundred MHz) range, since emission at these frequencies is easier to observe from extrasolar objects than optical emission. We combined the energy and radio power estimates with our previous flash density results (Hodosán et al. 2015, MNRAS, submitted) to estimate the minimum lightning occurrence rate on exoplanets and brown dwarfs that could produce radio signatures detectable with current technology.

Name: **Mark Hollands** (PhD Student)
Affiliation: The University of Warwick
Title: Ancient planetary systems at white dwarfs (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: The detection of metals in the atmospheres of many white dwarfs is sign-posting the presence of evolved planetary systems. The canonical model for the observed metal-pollution is the accretion of rocky debris from a tidally disrupted planetesimal, and has been unambiguously corroborated by the discovery of debris transiting WD1145+017.

Using SDSS spectra, we have identified remnants of planetary systems at over 200 cool and old white dwarfs, which finished their main-sequence lives between 1 and 8 Gyr ago. From the atmospheric abundance analysis on these stars we have determined the chemical composition of accreted material, and we find a rich variety in the chemistry of the parent bodies, e.g. crust-like vs. core-like material. We are also able to place a lower limits on the masses of the disrupted parent bodies, which range from 10^20g to 10^24g, equivalent to minor planets like Ceres.

This study may also provide insight into the history of rocky planet formation, as we find tentative evidence for a decrease in the number of strongly metal-polluted white dwarfs at increasing ages. If confirmed, it will provide direct constraints on the onset of rocky planet formation during the early history of the Milky Way.

Name: **Tiffany Kataria** (Post-Doc)
Affiliation: University of Exeter
Title: The atmospheric circulation of a nine-hot Jupiter sample: Probing circulation and chemistry over a wide phase space (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Even as we move towards characterizing smaller and cooler exoplanets, hot Jupiters continue to be the best transiting planets for probing the atmospheric properties of exoplanets and refining current theory. Here we present results from an atmospheric circulation study of nine hot Jupiters that comprise a large transmission spectral survey using the Hubble and Spitzer Space Telescopes. These observations exhibit a range of spectral behavior over optical and infrared wavelengths which suggest diverse cloud and haze properties in their atmospheres. By utilizing the specific system parameters for each planet, we naturally probe a wide phase space in planet radius, gravity, orbital period, and equilibrium temperature. First, we show that our model "grid" recovers trends shown in traditional parametric studies of hot Jupiters, particularly equatorial superrotation and increased day-night temperature contrast with increasing equilibrium temperature. We show how spatial temperature variations, particularly between the dayside and nightside and west and east terminators, can vary by hundreds of K, which could imply large variations in Na, K, CO and CH_4 abundances in those regions, assuming a pristine environment. These chemical variations can be large enough to be observed in transmission with high-resolution spectrographs, such as ESPRESSO on VLT, METIS on the E-ELT, or with MIRI and NIRSpec aboard JWST. We also compare theoretical emission spectra generated from our models to available Spitzer eclipse depths for each planet, and find that the outputs from our solar-metallicity, cloud-free models generally provide a good match to many of the datasets, even without additional model tuning. Although these models are cloud-free, we can use their results to understand the chemistry and dynamics that drive cloud formation in their atmospheres.

Name: **Graham Lee** (PhD Student)
Affiliation: University of St Andrews
Title: Atmospheric formation of mineral clouds in 3D radiative-hydrodynamic simulation of HD 189733b. (Oral)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: The modelling of cloud formation in atmospheres of extrasolar planets coupled to the atmospheric hydrodynamic and thermo-chemical properties has long been an open challenge. We present the first 3D RHD atmospheric simulation of the hot Jupiter HD 189733b which includes fully-coupled cloud formation. We time

dependently evolve the 3D radiative- hydrodynamic and kinetic dust formation equations with the resulting cloud structure fed back as an additional opacity source for the radiative transfer scheme. We model the cloud particles as a mix of mineral materials which change as they move through the different atmospheric thermo-chemical environments under the influence of gravity and hydrodynamic motions. Mean grain sizes are typically sub-micron (0.01 - 0.5 micron) above 1 bar with hotter equatorial regions containing the smallest grains. The most dense cloud regions occur near the terminator regions and deeper atmospheric layers. The thickest, main cloud layer is found to be at 100 mbar - 10 bar and uniform across longitude and latitude containing micron sized cloud particles. The cloud material composition significantly varies with different minerals dominating in latitude, longitude and depth, dependent on local thermo-chemical conditions. Silicate material such as MgSiO3[s] are found to be dominant in regions probed by transmission spectroscopy. Overall, these properties produce a complicated wavelength dependent opacity structure which has significant impacts on the hydrodynamics of the atmosphere. We present snapshot transmission and eclipse spectra of our simulation taking into account the cloud opacity. In conclusion, the addition of a detailed kinetic cloud formation models to the RHD adds significant non-uniform opacity to the atmosphere which has a dramatic effect on the thermodynamic structure.

Name: **Mark Marley** (Faculty (Permanent Staff))
Affiliation: NASA Ames Research Center
Title: Directly Imaged Giant Planets: What do we Hope to Learn? (Oral)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: As we move deeper into the era when direct imaging planet searches, like GPI and SPHERE, are discovering and characterizing new young giant planets, it is worthwhile to step back and review our science goals for young giant planets. Of course for individual planets we ideally would hope to measure mass, radius, atmospheric composition, temperature, and cloud properties, but how do these characteristics fit into our broader understanding of planetary system origin and evolution? In my presentation I will review both the specifics of what we hope to learn from newly discovered young worlds as well as how these characteristics inform our broader understanding of giant planets and planetary systems. I will illustrate with a case study of 51 Eri b, the young giant planet discovered last year by GPI. Finally I will look to the future and highlight the opportunities that will be afforded by future ground and space-based exoplanet imaging instruments.

Name: **Nathan Mayne** (Faculty (Permanent Staff))
Affiliation: University of Exeter
Title: Modelling Exoplanet Atmospheres: the University of Exeter and the UK Met Office (Oral)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: At the University of Exeter we are developing a theoretical framework with which to interpret current, and future observations of exoplanets and place them in context with our own planet.

I will present the results of our state-of-the art 1D and 3D models when applied to gas giants, i.e. transiting hot Jupiters, young giant planets and Brown Dwarfs. This includes treatments of the dynamics, chemistry and radiative transfer within these atmospheres. I will also overview how we incorporate our developments in the UK Met Office infrastructure, and detail the envisaged evolution of our modelling framework to more Earth-like planets as the observations evolve in this direction.

Name: **Stephane Mazevet** (Faculty (Permanent Staff))
Affiliation: Observatoire de Paris
Title: Ab initio modelling of planetary interiors (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: TBD

Name: **Marco Rocchetto** (PhD Student)
Affiliation: UCL
Title: Tau-REx: A next generation retrieval code for exoplanetary atmospheres (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Spectroscopy of exoplanetary atmospheres has become a well-established method for the characterisation of extrasolar planets. We here present a novel inverse retrieval code for exoplanetary atmospheres. TauRex (Tau Retrieval for Exoplanets) is a line-by-line radiative transfer fully Bayesian retrieval framework. TauRex includes the following features: 1) the optimised use of molecular line-lists from the Exomol

project; 2) an unbiased atmospheric composition prior selection, through custom built pattern recognition software; 3) the use of two independent algorithms to fully sample the Bayesian likelihood space: nested sampling as well as a more classical Markov Chain Monte Carlo approach; 4) iterative Bayesian parameter and model selection using the full Bayesian Evidence as well as the Savage-Dickey Ratio for nested models, and 5) the ability to fully map very large parameter spaces through optimal code parallelisation and scalability to cluster computing. We investigate the impact of Signal-to-Noise and spectral resolution on the retrievability of individual model parameters, both in terms of error bars on the temperature and molecular mixing ratios as well as its effect on the model's global Bayesian evidence.

Name: **Sarah Rugheimer** (Research Fellow)
Affiliation: University of St. Andrews
Title: Impact of UV on the Spectral Fingerprints of Earth-like Planets Orbiting FGKM Stars (Oral)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: The spectral type of the host star will influence our ability to detect atmospheric features with future space and ground based missions like JWST, GMT and horizon direct detection missions like HDST/LUVOIR. Specifically, the UV emission from a planet's host star dominates the photochemistry and thus the resultant observable spectral features. Using the latest UV spectra obtained by HST as well as IUE, we model Earth-like planets for a wide range of host stars and geological epochs from pre-biotic to modern Earth-like biology. We detail the results of stellar activity on the primary detectable atmospheric features that indicate habitability on Earth, namely: H_2O, O_3, CH_4, N_2O and CH_3Cl. Our model spectra of terrestrial planets spans a grid of FGKM host stars and is presented for the VIS/NIR (0.4 μm - 4 μm) and the IR (5 μm - 20 μm) wavelengths.

Name: **Felix Sainsbury-Martinez** (PhD Student)
Affiliation: University of Exeter
Title: Buoyancy Instabilities from Anisotropic Conduction in Stellar and Planetary atmospheres (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: In a low-collisionality plasma with a weak magnetic field, the convective instability requirement changes from an entropy dependence to a combination of the field orientation and temperature gradient. In such cases, two instabilities are known to be available, the MTI and the HBI. The HBI exhibits a number of non-linear effects – such as the restriction of vertical heat transport – that have been shown to play a key role in cool-core galaxy clusters. Here we give a brief overview of both instabilities before presenting initial results from our survey of the parameter regime in which the HBI might operate within smaller bodies; stellar and hot planetary atmospheres. We show that the key requirements for the HBI to operate are satisfied within portions of the outer regions of these atmospheres but that stabilization by magnetic tension presents a significant obstacle in both cases. Additionally, we give a brief overview of the 2D MHD simulations of the HBI which we performed to investigate the evolution of the instability in various environments.

Name: **David Skålid Amundsen** (Post-Doc)
Affiliation: Columbia University, NASA GISS and University of Exeter
Title: Simulations of HD 209458b using the UK Met Office Global Circulation Model, the Unified Model (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Observational constraints on hot Jupiter atmospheres are becoming increasingly abundant. Transmission spectra, emission spectra and phase curves reveal a large diversity in e.g. cloudiness, heat redistribution efficiency and bulk density, the controlling parameters behind which still remain uncertain or unknown. To study these problems we have adapted the UK Met Office Global Circulation Model (GCM), the Unified Model (UM), to hot Jupiters. The UM solves the full 3D Euler equations with a height-varying gravity, and uses the two-stream approximation and correlated-k method with state of the art opacities from ExoMol for accurate treatment of radiation transport. We will present the first results of our model, and apply it to HD 209458b. We will compare our results to existing results in the literature, providing constraints on the inherent uncertainty in these models, and to recent observations by computing synthetic emission spectra and phase curves from our simulations.

Name: **Scott Thomas** (PhD Student)
Affiliation: Institute of Astronomy, University of Cambridge
Title: In hot water: Temperature-dependent models of watery super-Earths (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: As measurements of super-Earth masses and radii become more precise, we seek to use them to constrain the planet's interior structure. However, the internal structure models used to interpret these observations often neglect thermal effects. This decision is justified by noting that any thermal expansion of a solid Earth-like planet is small. But these thermal effects may be significant if the planet consists of a large fraction of water---a so-called "waterworld".

We explored the extent to which modelling internal temperature dependence can influence the predicted radius of a watery super-Earth. In doing so, we developed models of watery super-Earths that include a comprehensive temperature-dependent equation of state for water. We found that incorporating these thermal effects induced significant changes in the radii of super-Earths compared to zero-temperature or isothermal models. The magnitude of the change can be up to 0.5 $R_\oplus$ under reasonable assumptions about surface pressure and temperature. The effect remains even at the high surface pressures that would be expected if the water layer were covered by a thick atmosphere.

This is significant in light of recent observations which have measured super-Earth radii to precisions of better than 0.1 $R_\oplus$. It is therefore important to ensure that these thermal effects are taken into account when attempting to interpret the structure of super-Earths if a water layer is assumed as part of the model.

Name: **Geoffrey Vallis** (Faculty (Permanent Staff))
Affiliation: University of Exeter
Title: Idealized 3D modelling of terrestrial exoplanetary atmosphere (Oral)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: I will present some work on modelling terrestrial planetary circulations, with emphasis on two topics. One is the transition from an Earth-like atmosphere to a tidally locked exoplanet. The second is the transition to a turbulent state in a baroclinic atmosphere in the limit of zero bottom drag, such as may occur on gas giants.

Name: **Jack Yates** (PhD Student)
Affiliation: University of Edinburgh
Title: "Atmospheric Habitable Zones": the Habitability of Cool Brown Dwarf Atmospheres (Poster)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: Recently discovered cool brown dwarfs are expected to have regions in their upper atmospheres with liquid water (in clouds), pressures between 0.1 and 10 bar and temperatures around 300 K - fulfilling most of the basic requirements for life as we know it.

Here we consider the habitability of brown dwarf atmospheres by analogy with terrestrial microbes, some of which appear to spend a large fraction of their lives in Earth's atmosphere (especially in clouds). We focus on the effects of atmospheric dynamics - organisms must be able to remain in the "habitable zone" without sinking to the hot lower atmosphere or floating up to the cold upper atmosphere.

Using a very simple 1D convection model and borrowing ideas from models of plankton at the sea surface (NPZ models), we show that organisms similar to terrestrial organisms could sustain a stable population for decades, assuming that there is sufficient "food" available for them to consume.

We denote this part of the atmosphere the "atmospheric habitable zone"; a region in a body's atmosphere that could sustain life, even if the surface is inhospitable or there is no surface. This region will move lower into the atmosphere as the body cools (barring inversions) and the body does not need to be in a circumstellar habitable zone for this region to exist (providing that the core is hot enough). If such regions are habitable, we may be drastically underestimating the abundance of habitable environments in the galaxy; gas giants, planets with inhospitable surfaces (such as Venus), free-floating brown dwarfs and other bodies could all possess an atmospheric habitable zone. Further work with better models and considerations of the chemical environment will be required to learn more about the habitability of these bodies.

Name: **Sergey Yurchenko** (Faculty (Permanent Staff))
Affiliation: University College London, Physics and Astronomy
Title: Opacities for modelling atmospheres of exoplanets (Oral)
Session: Modelling (Atmosphere, interior structure/evolution)
Abstract: The fundamental molecular data play principal role for spectral characterization of extrosolar planets. Despite the recent progress in this field (especially by ExoMol [1] project), the absorption data for a number of important species is still missing or incomplete. Some of the new opacity tables (so-called linelists) built for hot temperatures contain billions of lines (ExoMol's methane contains almost 10 billion transitions) and thus are computationally very demanding. The line broadening effects are still incomplete and inaccurate in the opacity databases even when the line positions and transition probabilities are known, especially for the hydrogen/helium dominated environments. The atmospheres of so-called lava planets containing vaporized rock compounds is a new challenge for modelling spectroscopy of these objects.

Much of this work is being undertaken by ExoMol project (www.exomol.com). The line lists for a number of key atmospheric species currently available from ExoMol (www.exomol.com). The most recent ExoMol updates include line lists for SO2, H2S, SO3, CaO, AlO, ScH, HNO3, and CS. The line lists in progress are for AlH, C2, SH, SiH, SO, TiH, TiO, VO, NO, NS, and C2H4. The status of laboratory spectroscopic data necessary for exoplanet characterisation will be reviewed.

This work is part of the ExoMol project supported by the ERC under Advanced Investigator Project 267219.

[1] J. Tennyson and S. N. Yurchenko, Mon. Not. R. Astron. Soc., 425, 21 (2012).

Session IV Planet Host Stars (asteroseismology, stellar activity)

Name: **Conny Aerts** (Faculty (Permanent Staff))
Affiliation: Institute of Astronomy, University of Leuven
Title: Asteroseismology of Exoplanet Host Stars (Oral)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: After a basic introduction on how asteroseismology works in practice, we illustrate its application to various kinds of stars but with emphasis on exoplanet host stars. We show how detected oscillation modes allow us to understand details of the interior structure of stars that are impossible to unravel otherwise. The talk will focus on the major questions of how stars rotate internally, what kind of mixing is active, and how that impacts on their age determination. We highlight the asset of asteroseismology as a practical tool for exoplanetary studies. We end by summarizing ongoing and future studies on the impact of stellar variability on exoplanetary atmospheres.

Name: **Rachel Booth** (PhD Student)
Affiliation: Queen's University Belfast
Title: An improved stellar age-activity relationship for ages beyond a gigayear (Poster)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: When the first bio-marker in an exoplanetary atmosphere is found, it will most likely be found in a planet orbiting an inactive, old nearby star. In order to assess this exoplanet's evolution, we will need to reliably estimate the age of the star, which is notoriously difficult for old field stars. Since Skumanich first presented evidence of a relationship between the rotation and the age of a star there has been much interest in developing a calibrated relationship which can be used to provide an estimate of a star's age. Currently these age-activity relationships become quite unreliable for ages over a gigayear. My research uses the advancement in asteroseismology which has allowed large samples of solar and late-type stars' ages to be determined and combines these with X-ray data from which I measure the stellar activity in order to derive a new and improved age-activity relationship for stars with ages greater than a gigayear.

Name: **Tiago Campante** (Post-Doc)
Affiliation: University of Birmingham
Title: Asteroseismology and Exoplanets — IVth Azores International Advanced School in Space Sciences (Poster)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: This International Advanced School covers two scientific topics that share many synergies and resources: Asteroseismology and Exoplanets. It is mainly aimed at PhD and MSc students (although postdocs are also encouraged to apply) in any field of Astrophysics. The science program aims at building opportunities for cooperation and sharing of methods that will benefit both communities. This cooperation has experienced great success in the context of past space missions such as CoRoT and Kepler. Upcoming photometry and astrometry from space, as well as complementary data from ground-based networks, will continue to foster this cooperation. Observations of bright stars and clusters in the ecliptic plane are being made by the repurposed K2 mission, and NASA's TESS and ESA's CHEOPS missions will soon start obtaining similar data over the entire sky. ESA's PLATO mission will then build upon these successes by providing photometric light curves on a wealth of stars. Ground-based spectroscopy from the Stellar Observations Network Group (SONG) will complement the satellite data for the brightest stars in the sky, as will also be the case with the new generation of high-precision spectrographs being developed for the ESO, like the Echelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations (ESPRESSO).

Name: **Guy Rhys Davies** (Post-Doc)
Affiliation: University of Birmingham
Title: Gyrochronology: Here be dragons (Oral)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: Gyrochronology is a method for estimating the ages of stars and hence exoplanets assumed to form at the same time. Gyrochronology or age-period-mass relations have been used extensively but remain calibrated primarily on young stars found in open clusters. Using asteroseismology we have recently explored previously

uncharted areas of the age-mass parameter space. Results show that stars more evolved than the Sun experience weakened magnetic braking not incorporated in the usual gyrochronology relations. This unexpected behaviour invalidates gyrochronology ages for older stars. This leaves gyrochronology as a method that works but not if stars are too young, too hot, or too old. I will present a new map of gyrochronology, dragons and all.

Name: **Raphaëlle Haywood** (Post-Doc)
Affiliation: Center for Astrophysics, Harvard Observatory
Title: Towards precise and accurate exoplanet mass determinations: HARPS-N observes the Sun (Oral)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: Planet-hunter by night and Sun-chaser by day, the HARPS-N spectrograph is now revealing the secrets at the heart of the magnetic activity-induced radial-velocity variations of our best-known star.

On Sun-like stars, these variations are dominated by the suppression of convective blueshift incurred by faculae. Many faculae are spatially associated with spots, but not all; for this reason, optical lightcurves can give only incomplete predictions of activity-induced radial-velocity variations. We must therefore identify a proxy to track faculae directly.

I am using simultaneous, high spatial resolution images from the Solar Dynamics Observatory to reconstruct the line profile shape resulting from individual solar surface features, such as faculae/plage, sunspots and granulation. I will scale and compare these synthetic line profiles with the cross-correlation functions obtained by HARPS-N, in the aim to identify a line-shape signature unique to faculae.

Developing our understanding of stellar radial-velocity variability is essential to determining precise and accurate masses of Neptune- and super-Earth-mass planets targeted by HARPS-N at night time, in readiness for the TESS, CHEOPS and PLATO missions.

Name: **Jessica Kirkby-Kent** (PhD Student)
Affiliation: Keele University
Title: Measuring Binary Parameters for Stellar Model Calibration. (Poster)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: Stellar evolutionary models play an important role within exoplanet research, as they are often required to determine the mass and age of the planet hosting star. These are key properties needed to understand the characteristics of exoplanets. However, there are known issues with current evolutionary models, in that they can under-predict the radii and over-predict the temperatures of low-mass stars. Different models also introduce uncertainties due to the different methods of implementing parameters such as convective overshooting, mixing length and helium abundance. Further work is needed to improve the accuracy of the models and improve our understanding of how these parameters should be incorporated.

Double-lined eclipsing binaries can be used to calibrate evolutionary models. We present the current results of a project to measure the masses and radii of four eclipsing binary systems to better that 1% accuracy, using high precision WASP photometry and high-resolution UVES spectra. With these precise values, along with effective temperatures and metallicities determined from the spectra, it will be possible to determine the age of the systems to good accuracy. This will make the stars in these binaries ideal candidates for calibrating evolutionary models.

Name: **Joe Llama** (Post-Doc)
Affiliation: University of St Andrews
Title: Transiting the Sun (Poster)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: High energy (X-ray / UV) observations of transiting exoplanets have revealed the presence of extended atmospheres around a number of systems. At such high energies, stellar radiation is absorbed high up in the planetary atmosphere, making X-ray and UV observations a potential tool for investigating the upper atmospheres of exoplanets. At these high energies, stellar activity can dramatically impact the observations. At short wavelengths the stellar disk appears limb-brightened, and active regions appear as extended bright features that evolve on a much shorter timescale than in the optical making it difficult. These features impact both the transit depth and shape, affecting our ability to measure the true planet-to-star radius ratio. I will present results of simulated exoplanet transit light curves using Solar data obtained in the soft X-ray and UV by NASA's Solar Dynamics Observatory to investigate the impact of stellar activity at these wavelengths. By using a limb-

brightened transit model coupled with disk resolved Solar images in the X-ray, extreme- and far-UV I will show how both occulted and unocculted active regions can mimic an inflated planetary atmosphere by changing the depth and shape of the transit profile. I will also show how the disk integrated Lyman-alpha Solar irradiance varies on both short and long timescales and how this variability can impact our ability to recover the true radius ratio of a transiting exoplanet.

Name: **Andrea Miglio** (Faculty (Permanent Staff))
Affiliation: School of Physics and Astronomy, University of Birmingham
Title: The symbiosis between asteroseismology and exoplanet studies: challenges for the next decade (Poster)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: Asteroseismology can provide the accurate and precise estimates of the stellar properties (i.e., density, surface gravity, mass, radius and age) that are needed to make robust inference on the properties of the planets, and information on the internal rotation and stellar angle of inclination to help better understand the evolutionary dynamics of planetary systems.

In this contribution I will give examples of “asteroseismology in action”, including the characterisation of a red giant planet host star observed by K2, and sharp-structure variations in the internal structure of Kepler exoplanet host stars. I will then insist on the factors that are currently limiting the accuracy of seismic inferences, in particular on the age of main-sequence and red-giant stars, and argue that significant progress will only be achievable by a deeper understanding of fundamental stellar physics.

Name: **Teo Mocnik** (PhD Student)
Affiliation: Keele University
Title: K2 Looks towards WASP-85, WASP-75, WASP-55 and Qatar-2 (Oral)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: A handful of WASP transiting exoplanet host stars have already been observed by the K2 in the short-cadence mode and made available to public, namely WASP-85, WASP-47 and WASP-75. Soon, WASP-55 and Qatar-2 data from K2 campaign 6 will be released. We constructed a data reduction procedure to restore the near-original Kepler-like photometric precision. We will present our data reduction procedure, the lightcurves, derived system parameters and starspot analysis for transiting hot Jupiter host stars WASP-85, WASP-75, WASP-55 and Qatar-2. The detected starspot occultation events on WASP-85A indicate that the planet's orbit is probably aligned with the star's rotational axis and suggests a stellar rotational period of 15.1+/-0.6 d, which is in agreement with the starspot rotational modulation period.

Name: **Charlotte Norris** (PhD Student)
Affiliation: Imperial College London
Title: Preliminary outcomes for 3D facular modelling (Poster)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: A radiative transfer algorithm (ATLAS9) has been used on magneto convection simulations for various stellar types at multiple angles. The ultimate goal of this will be to model the effects of viewing angle on the contrasts of faculae across stellar types and to improve the modelling of stellar photospheric variability. Starting with solar twins, we derive facular contrasts as a function of limb angle and compare these to contrast functions commonly adopted in the literature for exoplanet signal modelling. We discuss the wavelength dependence of the contrasts and include preliminary results from F and M stars.

Name: **Katja Poppenhaeger** (Faculty (Permanent Staff))
Affiliation: Queen's University Belfast; Harvard-Smithsonian Center for Astrophysics
Title: Putting a new spin on stellar activity: the tidal effects of Hot Jupiters on their host stars (Poster)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: Many exoplanets orbit their host stars at close distances, with semi-major axes of only a few stellar radii; this can influence the evolution of the planetary atmospheres as well as the evolution of the host stars themselves. While cool stars usually spin down with age and become inactive, an input of angular momentum through tidal interaction, as seen for example in close binaries, can preserve high activity levels over time. This may also be the case for cool stars hosting a Hot Jupiter. However, selection effects from planet detection methods may skew the activity levels seen in samples of exoplanet host stars, so caution is warranted. I will present a new method to investigate star-planet interaction effects in a bias-controlled manner, by using visual

proper motion binaries in which only one of the stars possesses a Hot Jupiter. This approach immediately rids one of the ambiguities of detection biases: with two co-eval stars, the second star acts as a negative control. I will present observational results on several outstanding systems which display significant age/activity discrepancies presumably caused by their Hot Jupiters.

Name: **Vinesh Rajpaul** (PhD Student)
Affiliation: University of Oxford
Title: Gaussian processes for modelling stellar activity and detecting planets (Oral)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: Stellar activity can induce RV variations which can drown out or even mimic planetary RV signals, and it is extremely difficult to model and thus mitigate these stellar signals. This is expected to be a major obstacle to using next-generation instruments to detect lower mass planets, planets with longer periods, and planets around more active stars. Enter Gaussian processes (GPs), which have a number of attractive features that make them very well suited to the joint modelling of stochastic activity processes and dynamical (e.g. planetary) signals. In this talk I'll present a GP-based framework for modelling RV time series jointly with ancillary activity indicators, allowing the activity component of RV time series to be constrained and disentangled from planetary components. Time permitting, I will also sketch a few other recent and promising applications of GPs in the context of exoplanet detection and characterisation.

Name: **Daniel Staab** (PhD Student)
Affiliation: Open University
Title: Chromospheric Activity of Transiting Planet Hosts: Mass Loss and Star Planet Interactions (Oral)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: We measured the chromospheric activity of the four hot Jupiter hosts WASP-43, WASP-51/HAT-P-30, WASP-72 & WASP-103 to search for anomalous values caused by the close-in companions. The Mount Wilson Ca II H & K S-index was calculated for each star using observations taken with the Robert Stobie Spectrograph at the Southern African Large Telescope. The activity level of WASP-43 is anomalously high relative to its age and falls among the highest values of all known main sequence stars. We found marginal evidence for activity enhancement for WASP-103. We suggest that for WASP-43 and WASP-103 star-planet interactions (SPI) may enhance the Ca II H & K core emission.

The activity of WASP-51/HAT-P-30 and WASP-72 is anomalously low, with the latter falling below the basal envelope for both main sequence and evolved stars. We attribute this to circumstellar absorption due to planetary mass loss, though absorption in the ISM may contribute. We highlight the large fraction (24%) of known short period planet hosts with anomalously low apparent activity levels, including systems with hot Jupiters and low mass companions. Since SPI can elevate and absorption can suppress the observed chromospheric activity of stars with close-in planets, their Ca II H & K activity level is an unreliable age indicator. Systems where the activity is depressed by absorption from planetary mass loss are key targets for examining planet compositions through transmission spectroscopy.

Name: **Andrew Thompson** (PhD Student)
Affiliation: Queen's University Belfast
Title: Determining the Spot Coverage of Exoplanet Host Stars (Poster)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: With the push towards finding ever smaller exoplanets, the effects of astrophysical noise (e.g. starspots) on limiting the detection of such planets is becoming more pronounced. We investigate the effects that such stellar activity would have on the spectrum of exoplanet host stars. We look at measuring changes to temperature sensitive lines with the hope of better constrain the absolute spot coverage of exoplanet host stars and hope to use this as a tool to better identify the nature of variations seen within spectra.

Name: **Christopher Watson** (Faculty (Permanent Staff))
Affiliation: Queen's University Belfast
Title: Towards Earth-analogues: overcoming convection (Oral)
Session: Planet host stars (Asteroseismology, stellar activity)
Abstract: Stellar convective motions (and its interaction with magnetic fields) is now widely thought to represent the limiting factor in the radial-velocity (RV) detection of Earth-analogues. The hot rising granules and sinking

intergranular material cause RV 'noise' of the order of ~1 m/s, masking the subtle ~10 cm/s Doppler wobble signal expected from an Earth-twin. With new highly stabilised spectrographs (such as ESPRESSO on the VLT, due to see first-light soon) promising 10 cm/s RV instrumental precisions, understanding convection is critical. Our group at QUB has been using 3D MHD models of convection, borrowed from the theoretical tool-kit of solar physicists, to probe the impact of convection and explore diagnostics for removing its effects. I will provide an overview of this work and highlights arising from it, and look to its potential for the future.

Session V Planet Formation

Name: **Philip Carter** (Post-Doc)
Affiliation: University of Bristol
Title: Compositional evolution of growing terrestrial planet embryos (Oral)
Session: Planet formation
Abstract: Our own solar system provides key benchmarks for theories of planet formation, particularly via detailed compositional information both from the Sun and from meteorites. We can study planetary evolution by examining the deviation of observed planetary compositions from the composition of primitive meteorites. The Earth appears to be non-chondritic in its abundances of refractory lithophile elements, posing a significant problem for our understanding of its formation and evolution. It has been suggested that this difference may be explained by collisional erosion of differentiated planetesimals. Here we present the results of N-body simulations of terrestrial planet formation that include a state-of-the-art collision model and track the core mass fraction of the growing planetary embryos. We show that the accretion process during the runaway and oligarchic growth phases can naturally lead to a change in the bulk composition of the final embryos. With significant dynamical excitation enough mantle can be stripped from growing embryos to account for the Earth's non-chondritic Fe/Mg ratio.

Name: **Gavin Coleman** (PhD Student)
Affiliation: Queen Mary University of London
Title: Forming Giant Planets in Radially Structured Discs (Oral)
Session: Planet formation
Abstract: Exoplanet observations have found a bimodal distribution for giant planets, those that orbit close to their parent star with periods less than 10 days, and those that orbit far from the star with periods greater than 100 days. Recently models have emerged to explain the formation of giant planets close to their parent star through various forms of in-situ formation. Forming giant planets far from their central star has proven difficult due to an inability for giant planet cores to overcome strong inward type I migration. Currently no theories have been able to form giant planets of both populations simultaneously, whilst also being unable to establish the reason for the observed lack of giant planets in the valley between the two populations. I present here that by incorporating radial structures within a protoplanetary disc, similar to those observed in HL Tau, giant planets can form at realistic disc locations before migrating to their final orbital positions.

Name: **Cornelis Dullemond** (Faculty (Permanent Staff))
Affiliation: Heidelberg University
Title: Observational signatures of planet formation in disks (Oral)
Session: Planet formation
Abstract: The most important test of any planet formation theory is whether it can explain (or at least is not in conflict with) known exoplanet statistics. However, with the ALMA telescope array and the high resolution scattered light images of protoplanetary disks emerging in recent years, there is hope to find signatures of planet formation in progress, by its effects on the disk structure. In this talk I will discuss some of these possibilities and recent progress along these lines.

Name: **Daniel Evans** (PhD Student)
Affiliation: Keele University
Title: High-resolution Imaging of Transiting Extrasolar Planetary systems (HITEP) (Poster)
Session: Planet formation
Abstract: We present the initial results of an ongoing search for close stellar companions to 101 transiting exoplanet systems in the Southern hemisphere. The presence, or lack of, distant stellar companions is a key discriminator between several competing theories for hot Jupiter formation, whilst both physically associated and background stars are important sources of contaminating light for both photometric and spectroscopic observations. This is the first survey to concentrate on transiting exoplanets in the South, and was performed using the Lucky Imager on the Danish 1.54m telescope at La Silla, which is capable of simultaneous observations in two colours. We provide the first astrometric and photometric measurements of 28 candidate companions located within 5 arcseconds of a host star, as well as follow up observations of 23 previously identified companions. For a subset of targets, we are able to analyse whether the candidate companions show common proper motion with the planet host star, or to compare the distances to the two stars based on two colour

photometry. We have also investigated how the measured fraction of wide binaries among solar type stars compares to our sample of detected companions around hot Jupiter host stars, finding that the two may not be as different as has previously been claimed.

Name: **Mark Fletcher** (PhD Student)
Affiliation: University of Leicester
Title: Novel model for debris discs - planet correlations (Poster)
Session: Planet formation
Abstract: Debris discs (DD) are supposed to be the left over material not used in formation of planets. DD frequency of detection should hence be higher around metal rich and planet-bearing stars. Shockingly, observations do not support this prediction at all. I explore the role of DDs in the new planet formation theory called Tidal Downsizing (TD). In this theory, the relation between planets and DDs is reversed. DDs form when very young gas giant planets are disrupted (Nayakshin & Cha 2012), which may lead to very different DD-planet and metallicity correlations. Using the recently developed population synthesis framework (Nayakshin & Fletcher 2015), I investigate how frequency of DDs and planet formation of different types depends on the metallicity of the host star. I then study the correlations between the DDs and planets. I find a correlation of DDs with the presence of super Earths with a higher than average occurrence rate in systems with super Earths. There is also a broad spread of DD formed at all metallicities, with no obvious metallicity dependence. I find an additional group of metal rich DD created by partial disruptions of the metal rich gas giants. Our models provide a far more convincing explanation for the observed DD properties than the classical Core Accretion model.

Name: **Duncan Forgan** (Post-Doc)
Affiliation: University of St Andrews
Title: Fragmentation in Magnetised Self-Gravitating Discs (Poster)
Session: Planet formation
Abstract: We present some early results of 3D smoothed particle magnetohydrodynamics experiments in self-gravitating discs with magnetic fields. We investigate the suppressing action of magnetic fields on the fragmentation process using simple parametrisations of the cooling rate and magnetic field strength. We show there is a new non-convergence problem exclusive to MHD simulations of self-gravitating discs, and quantify the properties of the fragments produced.

Name: **Edward Gillen** (Post-Doc)
Affiliation: University of Cambridge
Title: The first low-mass, pre-main sequence eclipsing binary with evidence of a circumbinary disk (Poster)
Session: Planet formation
Abstract: We present CoRoT 223992193, a new double-lined, detached eclipsing binary, which comprises two pre-main sequence M dwarfs and shows evidence of a circumbinary disk. This unique system, which could be a precursor of the circumbinary planetary systems discovered by Kepler, enables us to investigate the interaction between a close binary and a circumbinary disk in a manner so far unavailable. I will present our detailed modelling of the spectral energy distribution, simultaneous CoRoT and Spitzer light curves, and VLT/FLAMES H-alpha profiles. Together, these constrain the system geometry and allow us to propose a framework to explain the complex photometric and spectroscopic observations of this unique system.

Name: **Cassandra Hall** (PhD Student)
Affiliation: University of Edinburgh
Title: Directly observing continuum emission from self-gravitating spiral waves in protostellar discs (Poster)
Session: Planet Formation
Abstract: Recent observations of several protostellar systems have revealed extended spiral structure. We use self- consistent analytical models to examine the possibility that this structure could be due to disc self- gravity.

Name: **Paul Hallam** (PhD Student)
Affiliation: Queen Mary University of London
Title: Investigating the depth of Gaps formed by Planets in Protoplanetary Discs (Poster)
Session: Planet formation
Abstract: It is known that angular momentum exchange between a protoplanetary disc and embedded massive planet can result in the opening of a gap in the disc. We study the relation between gap depth and planet mass using one dimensional and two dimensional hydrodynamic simulations. We then investigate the discrepancy between the results of these models.

Name: **Guillaume Laibe** (Post-Doc)
Affiliation: University of Saint Andrews
Title: Clouds above protoplanetary discs (Oral)
Session: Planet formation
Abstract: We show that gas drag, coupled with a turbulent, stratified disc, can actually act to support clouds of dust particles at several disc scale heights. This increases the segregation of dust grains, ruling out the concept of well-mixed discs. The presence of dusty clouds will modify the energy balance of the disc, its internal temperature and its chemistry. Such discs will have have larger near-IR excess and a less flared structure compared to well-mixed models. The supported dust clouds can help solve some major issues with protoplanetary discs. These are the presence of micron-sized grains at higher than expected latitudes, the self-shadowing of discs and potentially the crystalline inclusions in chondrules.

Name: **Stefan Lines** (Post-Doc)
Affiliation: University of Exeter
Title: Forming the Kepler circumbinary planets: Is in-situ growth possible? (Poster)
Session: Planet formation
Abstract: Recently discovered circumbinary planets provide a stringent test for planet formation models by requiring planets to form in a particularly extreme, dynamically hot environment. Gravitational perturbations on the disk from the stellar binary drive up the eccentricities and impact velocities of the planetesimals, increasing their tendency to undergo disruptive collisions during the core accretion phase of planet formation. The gaseous component of the accretion disk is similarly affected. The gravitational interaction between the gas disk and the stellar binary can lead to a highly asymmetric, precessing disk. Planetesimals feel this time-dependent gas disk which stirs up their eccentricities further and increases the likelihood of erosive, growth-inhibiting collisions between them. Despite the apparent difficulty in growing terrestrial planets and giant planet cores in such systems, Kepler has discovered a number of planets in short-period circumbinary, P-type orbits. In this work we address the question, 'Could the Kepler circumbinary planets have formed in-situ?' by conducting N-body, fluid and hybrid simulations of these hostile circumbinary disks.

Name: **Pablo Loren-Aguilar** (Post-Doc)
Affiliation: University of Exeter
Title: Toroidal vortices as a solution to the dust migration problem (Oral)
Session: Planet formation
Abstract: We have identified a new type of dynamical dust–gas instability in protoplanetary discs that produces global toroidal vortices, due to the process of dust settling. We have investigated the evolution of a dusty protoplanetary disc with two different dust species (1 mm and 50 cm dust grains), under the presence of the instability. We show how toroidal vortices, triggered by the interaction of mm grains with the gas, stop the radial migration of metre-sized dust, potentially offering a natural and efficient solution to the dust migration problem.

Name: **Alexander James Mustill** (Post-Doc)
Affiliation: Lund University
Title: The effects of dynamics on the multiplicities of Kepler planets (Poster)
Session: Planet formation
Abstract: The statistics of planet candidates from the Kepler mission reveal a large number of systems with single transiting planets relative to multiple systems. This excess cannot be ascribed merely to the lower probability of seeing multiple planet systems in transit, regardless of mutual inclinations, and appears to reflect a genuine surplus of single-planet systems compared to multiple systems within the regions probed by Kepler. I present ongoing work aimed at addressing whether the single systems may evolve out of the multiples by dynamical

interactions: do all inner systems form multiple but many lose all but one (or all) of their planets? I recently showed (Mustill, Davies & Johansen 2015) that high-eccentricity migration of hot Jupiters efficiently clears out all inner planets, and the high failure rate for high-eccentricity migration suggests that many more inner systems may be damaged by “failed” hot Jupiters. I present extensive N-body simulations of inner planetary systems based on the Kepler candidates exposed to two scenarios: planet—planet scattering among outer giants, and Kozai cycles on an outer giant induced by a binary. In each case around 1 in 4 of the systems lose at least one inner planet. The mutual inclinations in the inner systems that survive are not strongly excited in most cases. I also investigate the role of non-perfect mergers between planets in tightly-packed unstable inner systems when they collide, which because of the extreme orbital velocities of the planets discovered by Kepler may cause significant loss of mass — and hence harder detectability — for planets involved in collisions. This, too, seems not to produce single-planet systems in the numbers needed. I conclude that most of the single-planet systems discovered by Kepler formed as single planets, at least within Kepler’s detection limit of ~1 au.

Name: **Soko Matsumura** (Faculty (Permanent Staff))
Affiliation: University of Dundee
Title: Effects of Dynamical Evolution on Compositions of Planets (Oral)
Session: Planet formation
Abstract: We explore how the compositions of terrestrial planets in the Solar System are affected by dynamical evolution of giant planets. The initial compositions of building blocks of the rocky planets are estimated by using a simple condensation model, and the compositions of planets are determined through numerical simulations of planet formation. We find that the abundances of refractory and moderately volatile elements are nearly independent of formation models, and that all the models could reproduce the abundances of these elements of the Earth. The abundances of more volatile (atmophile) elements, on the other hand, depend on the scattering efficiency of icy planetesimals into the inner disc as well as the mixing efficiency of the inner planetesimal disc. We show the outcomes of three formation models of terrestrial planets in the Solar System and discuss their differences.

Name: **Matthew Mutter** (PhD Student)
Affiliation: Queen Mary University of London
Title: The Impact of Self-Gravity on Circumbinary Disc and Planet Evolution. (Poster)
Session: Planet formation
Abstract: Explaining the observed state of the growing catalogue of Kepler circumbinary planets requires understanding the parent disc in which they formed. Identifying the key physical processes which shape these discs' structure and dynamics is vital for understanding the planets' final orbital configuration and properties.
We present the latest results of work being undertaken on disc and planet evolution in circumbinary systems. Using 2D hydrodynamic simulations we examine the role of disc self-gravity and mass, in a subset of the Kepler circumbinary systems, on disc evolution and structure, as well as the evolution of embedded protoplanets in these environments. The choice of inner boundary condition and type is examined in these systems.
In high-mass discs we observe significant modifications to the disc structure and dynamics from the low-mass models. The additional structures we observe have interesting consequences for the evolution of planets these discs host.

Name: **Andrew Shannon** (Post-Doc)
Affiliation: University of Cambridge
Title: The unseen planets of double belt debris disk systems (Poster)
Session: Planet formation
Abstract: The gap between two component debris disks is often taken to be carved by intervening planets scattering away the remnant planetesimals. We employ N-body simulations to determine how the time needed to clear the gap depends on the location of the gap and the mass of the planets. We invert this relation, and provide an equation for the minimum planet mass, and another for the expected number of such planets, that must be present to produce an observed gap for a star of a given age. This is thus a natural complement to direct imaging searches in such systems, which typically constrain the maximum planetary system that might be present.

Name: **Jean Teyssandier** (Post-Doc)
Affiliation: DAMTP - University of Cambridge
Title: Growth of eccentric modes in disc-planet interactions (Oral)
Session: Planet formation
Abstract: The origin and wide distribution of eccentricities in planetary systems remains to be explained, in particular in the context of planet-disc interactions. In Teyssandier & Ogilvie (2016), we have formulated a set of linear equations that describe the behaviour of small eccentricities in a protoplanetary system consisting of a gaseous disc and a planet. Eccentricity propagates through the disc by means of pressure and self-gravity, and is exchanged with the planet via secular interactions. Excitation and damping of eccentricity can occur through Lindblad and corotation resonances, as well as viscosity. In this talk I will present a study of the eccentric modes of the coupled disc-planet system in the case of short-period giant planets orbiting inside an inner cavity, possibly carved by the stellar magnetosphere. Three-dimensional effects allow for a mode to be trapped in the inner parts of the disc. This eccentric mode can easily grow within the disc's lifetime. An eccentric mode dominated by the planet can also grow, although less rapidly. I will present the structure and growth rates of these modes and their dependence on the assumed properties of the disc. Finally, the linear theory will be compared with numerical simulations, and I will discuss the implication of these results for the eccentricity distribution of planetary systems.

Session VI Future Instruments and Perspective

Name: **Martin Dominik** (Faculty (Permanent Staff))
Affiliation: SUPA, University of St Andrews
Title: “GravityCam” – Ground-based wide-field high-resolution imaging and high-speed photometry (Poster)
Session: Future instruments and perspective
Abstract: Ongoing progress in the development of the technique of Lucky Imaging demonstrates that high-resolution optical imaging is no longer the sole domain of space-based telescopes. As compared to Adaptive Optics, Lucky Imaging can correct for the blurring effect caused by the Earth’s atmosphere over a much larger patch of sky and with much fainter reference stars. GravityCam is being designed to be the first of a new class of versatile instruments for telescopes of 2.5–4 m diameter with wide-ranging applications, opening up two entirely new windows to ground-based astronomy: wide-field high-resolution imaging and wide-field high-speed photometry.

Name: **Sasha Hinkley** (Faculty (Permanent Staff))
Affiliation: University of Exeter
Title: Spectroscopic Characterization of Exoplanets at VLT and E-ELT (Oral)
Session: Future instruments and perspective
Abstract: I will present an overview of the how the direct imaging of exoplanets is already starting to provide detailed spectroscopy of exoplanets, allowing us to gather all of the detailed spectroscopic information (e.g. atmospheric compositions and conditions) that have been gathered for stars over the last century. I will give an overview of the most promising suite of upcoming instrumentation at the VLT dedicated to this task, as well as provide a brief overview of the most promising suite of instrumentation for the next generation of instrumentation on the 39m E-ELT in 2025. In addition to providing high resolution mid-infrared spectroscopy of Jovian-mass exoplanets, this instrumentation has the potential to return the first images and spectroscopy of earth-like planets. These endeavors will reach beyond the study of exoplanets, influencing subfields as diverse as atmospheric science and astrobiology, and are critical for the future identification of biosignatures on Earthlike extrasolar planets.

Name: **James McCormac** (Post-Doc)
Affiliation: University of Warwick
Title: NGTS - The Next Generation Transit Survey (Poster)
Session: Future instruments and perspective
Abstract: The Next Generation Transit Survey (NGTS) is a new wide-field transiting exoplanet survey aimed at discovering Neptune and super-Earth size exoplanets around bright (V<13) stars in the solar neighbourhood. NGTS is now routinely observing the southern sky from ESO's Paranal observatory, Chile. It consists of an array of 12 robotically operated telescopes observing in the 600-900 nm band; hence maximising the sensitivity to small but bright K and M dwarf stars. Observing K and early M type stars theoretically permits the detection of smaller transiting exoplanets as the radius of the host star is reduced compared to solar-type stars. Simulations have shown that NGTS will survey more than five times the number of stars with V<13 than Kepler and will therefore provide the brightest targets for characterisation with existing and future instrumentation (VLT, E-ELT and JWST). Many recent discoveries of planetary systems harbouring Neptune-mass planets and super-Earths clearly indicate that low-mass planets around solar-type stars are very common. Paranal boasts exceptional photometric conditions and a low atmospheric water vapour content for a significant fraction of the year, which is essential for NGTS to perform photometry at the required millimagnitude level or better. The NGTS project is made up of partners from the University of Warwick, University of Leicester, University of Cambridge, Queen's University Belfast, Observatoire de Geneve and DLR Berlin. NGTS builds on the experience of the SuperWASP project, which, for many years, has lead the ground-based detection of transiting exoplanets.

Name: **David Mouillet** (Faculty (Permanent Staff))
Affiliation: Institut de Planétologie et d'Astrophysique de Grenoble
Title: An overview on new instruments for exoplanet imaging and perspective (Oral)
Session: Future instruments and perspective
Abstract: In the last decade, a new generation of instruments has been developed specifically for high contrast imaging on large telescopes. Such instruments now in operation significantly widen our capability to image young planetary systems and characterize individual giant planets at large separation. After illustrating some of these new capabilities, I will also discuss the lessons learnt on the instrumental perspective and the prospects for the future. I will distinguish medium-term projects, already started, and longer-term and more ambitious goals, for both ground-based and space-based instruments. I will briefly review the on-going instrumental research work in this context and the corresponding expected scientific impact.

Name: **Ian Parry** (Faculty (Permanent Staff))
Affiliation: University of Cambridge
Title: SUPERSHARP - a space telescope for direct imaging and spectroscopy of exoplanets (Oral)
Session: Future instruments and perspective
Abstract: I will describe SUPERSHARP (Spinning Unfolding Primary for Exoplanet Reconnaissance via Spectroscopic High Angular Resolution Photography) which is a space telescope concept where the design is driven by exoplanet science goals. SUPERSHARP will be proposed to ESA as a possible M5 mission. The many science drivers include the possibility of detecting bio-signatures in the spectra of Earth-like planets in the habitable zone. Conventional thinking is that such a telescope has to be very expensive ($2 billion or more) so the big challenge in the context of M5 is affordability. I will therefore introduce some new ideas which potentially allow SUPERSHARP to be significantly more affordable than previous telescope concepts.

Name: **Enzo Pascale** (Faculty (Permanent Staff)
Affiliation: Cardiff University
Title: The EXoplanet Climate Infrared Telescope (EXCITE) (Poster)
Session: Future instruments and perspective
Abstract: The EXoplanet Climate Infrared Telescope (EXCITE) is a proposed balloon spectrometer operating in the 1-5 micron band of the electromagnetic spectrum. EXCITE is designed to have sufficient sensitivity and control of systematics to measure phase curves of known transiting hot Jupiters and Neptunes, as well as their emission and transmission spectra. This would for the first time allow us to place strict observational constraints on the nature of exo-atmospheres and on models of planetary formation. In this poster we review the balloon mission concept, instrument design and science capabilities.

Name: **Don Pollacco** (Faculty (Permanent Staff))
Affiliation: University of Warwick
Title: Upcoming Space Experiments (Poster)
Session: Future instruments and perspective
Abstract: I will discuss what advances we might expect from the next generation of space experiments. In addition I will present some new concepts that are currently not selected but may be over the next decade.

Name: **Giovanna Tinetti** (Faculty (Permanent Staff))
Affiliation: UCL
Title: The science of ARIEL (Oral)
Session: Future instruments and perspective
Abstract: ARIEL is a European mission being planned to answer fundamental questions about how planetary systems form and evolve. ARIEL will investigate the atmospheres of several hundred planets orbiting distant stars. It is one of three candidate missions selected by the European Space Agency (ESA) for its next medium class science mission, due for launch in 2026. The ARIEL mission concept has been developed by a consortium of more than 50 institutes from 12 countries, including UK, France, Italy, Germany, the Netherlands, Poland, Spain, Belgium, Austria, Denmark, Ireland, and Portugal.

During its 3.5-year mission, ARIEL will observe hundreds of exoplanets ranging from Jupiter- and Neptune-size down to super-Earth and Earth-size in a wide variety of environments. The main focus of the mission will be on exotic, hot planets in orbits very close to their star. Hot exoplanets represent a natural laboratory in which to study the chemistry and formation of exoplanets. In cooler planets, different gases separate out through condensation and sinking into distinct cloud layers. The scorching heat experienced by hot exoplanets overrides these processes and keeps all molecular species circulating throughout the atmosphere.

ARIEL will have a meter-class mirror to collect visible and infrared light from distant star systems. The analysis of ARIEL spectra and photometric data will allow to extract the chemical fingerprints of gases and condensates in the planets' atmospheres, including the elemental composition for the most favourable targets. It will also enable the study of thermal and scattering properties of the atmosphere as the planet orbit around the star.

ARIEL will be placed in orbit at Lagrange Point L2 to maximise the thermal stability and field of regard, and therefore its options for observing exoplanets discovered previously by other missions.

Name: **John Young** (Post-Doc)
Affiliation: University of Cambridge
Title: HARPS3 at the Isaac Newton Telescope: robotic control overview (Poster)
Session: Future instruments and perspective
Abstract: The HARPS3 instrument is planned for installation on an upgraded and roboticized Isaac Newton Telescope by end-2018. HARPS3 will be a high resolution (R ~ 100,000) echelle spectrograph operating at wavelengths from 380 nm to 690 nm, with a design based on the successful HARPS and HARPS-N instruments. It is being built as part of the Terra Hunting Experiment – a future planned 10 year radial velocity measurement programme to discover Earth-like exoplanets. We present a high-level overview of the observatory, telescope and instrument control systems that are being designed to achieve reliable, automatic execution of science observations with HARPS3, and describe our strategies for collecting, processing, and archiving science and engineering data.

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