UK Exoplanet
Community Meeting

15 - 17 March 2017, St Andrews

Full programme and abstract book

Programme

The conference will start on Wednesday 15th March 2017 at 8:45am and close on Friday 17th March 2017 at 3pm. There will be 6 main science sessions, 8 parallel discussion sessions, and a poster session. A detailed program and all abstracts can be found in this document.

Main science sessions

- Atmospheres of Exoplanets: Observations
- Atmospheres of Exoplanets: Modelling
- Detection and Characterisation of Exoplanets
- Properties of the host star
- Discs and Planet Formation
- Links to the Solar System

Discussion sessions

- A. Bonsor & O. Shorttle: What can we learn from Earth?
- H. Cegla & R. Haywood: Stellar activity in exoplanet surveys
- S. Casewell: Brown dwarfs as proxies for exoplanets
- N. Mayne: Exoplanet modelling
- F. Meru: The disc-planet connection
- V. Parmentier: Prospects to understand cloudy exoplanets
- P. Rimmer: Laboratory Exoplanet Science
- S. Rugheimer: Workshop on using the JWST simulator, PandExo

Posters

Posters will be up outside the lecture hall for the entire duration of the conference. There will be ample time to watch them, during coffee breaks, lunches and the wine & cheese moment.

There will be poster pop-ups on Thursday during the main science sessions. These pop-ups will be very short (30 seconds, 1 slide) and not mandatory. If you would like to participate in these pop-ups, please send your slide at the latest on **Wednesday 15th March 1pm in pdf format** to Duncan Forgan: dhf3@st-andrews.ac.uk.

Social events

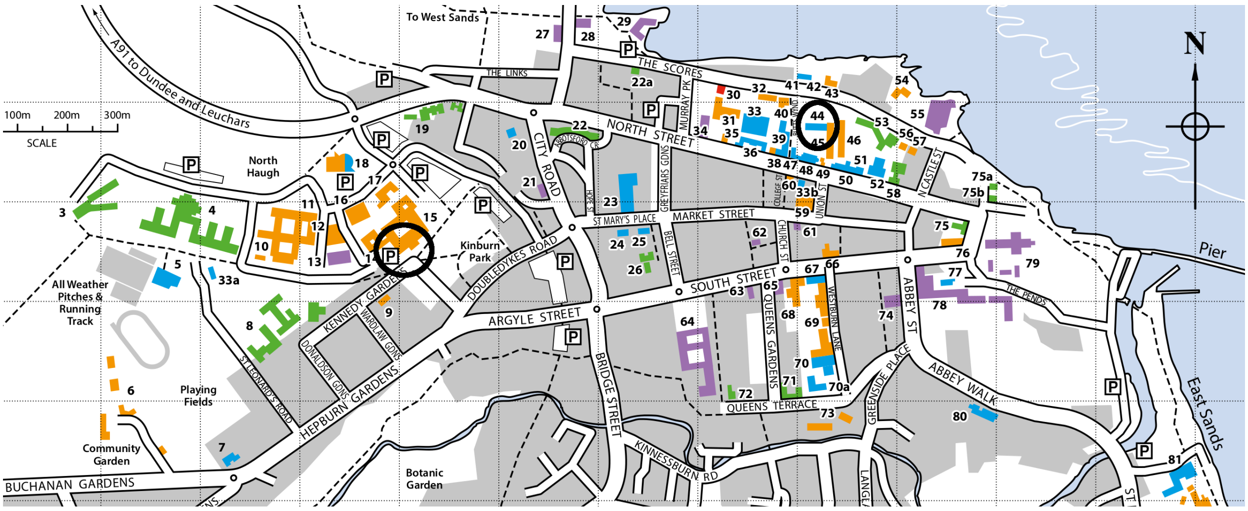
Wednesday night, there will be a poster session, whilst wine & cheese will be served, kindly funded by the RAS.

Thursday night, the optional conference dinner will be held, followed by a traditional ceilidh. Bring your coloured ticket with you. There is no dress code. Highland attire is welcomed, but not necessary.

Location

The UK exoplanet community meeting 2017 is being held in the School of Physics and Astronomy, University of St Andrews, located at North Haugh (postal code KY16 9SS - between nr 14 and 15 on the map).

The conference dinner and ceilidh will be held in Lower and Upper College Hall (nr 44 on the map).



Wednesday 15th March 2017

08:45-09:00 Welcome by Christiane Helling

Session I Atmospheres of Exoplanets: Observations (Chair: C. Helling)

09:00-09:30 D. Apai: Extrasolar Storms, review (US)

09:30-09:45 D. Armstrong: The first detection of variability in a Hot Jupiter atmosphere (Warwick)

09:45-10:00 L. Delrez: Probing the emission spectra of two ultra-hot Jupiters using ground-based occultation photometry (Cambridge)

10:00-10:15 B. Biller: Discovering the youngest free-floating planets: a transformative survey of Taurus with the novel W-band filter (Edinburgh)

10:15-10:30 N. Nikolov: VLT FORS2 comparative transmission spectral survey of clear and cloudy exoplanet atmospheres (Exeter)

10:30-10:45 J. Spake: Spectroscopic phase curves of hot Jupiters (Exeter)

10:45-11:00 A. Triaud: A septet of earths in the TRAPPIST-1 system (Cambridge)

11:00-11:30 Coffee

Session II Atmospheres of Exoplanets: Modelling (Chair: I. Baraffe)

11:30-11:50 R. Pierrehumbert: Dynamics of condensible-rich atmospheres on tide-locked exoplanets (Oxford)

11:50-12:10 I. Boutle: Exploring the climate of Proxima B with the Met Office Unified Model (MET Office)

12:10-12:25 M. Hammond: Modelling the climate of 55 Cancri e (Oxford)

12:25-12:40 S. Lines: Cloud formation and evolution in hot Jupiter atmospheres (Exeter)

12:40-12:55 T. Louden: Modelling the phase curve and occultation of WASP-43b with SPIDERMAN (Warwick)

13:00-14:00 Lunch

14:00-15:30 Discussion sessions

* Heather Cegla & Raphaëlle Haywood: Discussion and Q&A: Stellar Activity in Exoplanet Surveys
* Nathan Mayne: Exoplanet modelling
* Paul Rimmer: Laboratory Exoplanet Science
* Sarah Rugheimer: Workshop on using the JWST simulator, PandExo

15:30-16:00 Coffee

16:00-16:15 V. Parmentier: Cloudy nights on exoplanets (Arizona)

16:15-16:30 G. Lee: Modelling combined scattering and emission spectra using Monte Carlo radiative transfer (St Andrews)

16:30-16:45 A. Rushby: The carbonate-silicate cycle on Earth-like planets near the end of their habitable lifetimes (NASA AMES)

16:45-17:00 E. Lopez: Predictions for the transition between rocky super-Earths and gaseous sub-Neptunes (Edinburgh)

17:00-17:15 J. Owen: The early lives of low-mass exoplanet atmospheres (Princeton)

17:15-17:30 S. Daley-Yates: Magnetic Exoplanets: Interacting Fields and Flows (Birmingham)

17:30-19:30 Wine & Cheese and poster viewing

Thursday 16th March 2017

Session III Detection and Characterisation of Exoplanets (Chair: D. Sing)

09:00-09:30 M. Jardine: Exoplanet environments, review (St Andrews)

09:30-09:45 E. Gillen: Young transiting planets in the K2 clusters (Cambridge)

09:45-10:00 A. Cameron: The CHEOPS transit photometry mission (St Andrews)

10:00-10:15 G. Tinetti: ARIEL-Atmospheric Remote-Sensing Infrared Exoplanet Large-survey (UCL)

10:15-10:30 C. Boehm/A.Sozzetti: THEIA-a new astrometry mission to search for exoplanets (Durham/INAF)

10:30-11:00 Poster pop-ups (chair: D. Forgan)

11:00-11:30 Coffee

11:30-11:45 S. Thompson: HARPS3 and the Terra Hunting Experiment (Cambridge)

11:45-12:00 H. Jones: Planets around nearby M dwarfs (Hertfordshire)

12:00-12:15 H. Cegla: Cautionary Tales of Rossiter-McLaughlin Analyses (Geneva)

12:15-12:30 M. Guenther: Needle in a haystack: distinguishing planets from false positives with NGTS (Cambridge)

12:30-12:45 I. Waldmann: Deep learning in exoplanet spectroscopy (UC London)

12:45-13:00 S. Casewell: The direct detection of an irradiated brown dwarf in an eclipsing binary (Leicester)

13:00 Conference photo

13:00-14:00 Lunch

14:00-15:30 Discussion sessions

* Amy Bonsor & Oliver Shorttle: Exoplanets: what can we learn from Earth?
* Sarah Casewell: Brown dwarfs as proxies for exoplanets
* Farzana Meru: The disc-planet connection: from planet formation to planet observations
* Vivien Parmentier: Prospects to understand cloudy exoplanets

15:30-16:00 Coffee

Session IV Properties of the host star (Chair: Y. Unruh)

16:00-16:15 A. Bonsor: The Compositional Diversity of Exoplanetary Material (Cambridge)

16:15-16:30 H. Giles: Determining starspot lifetimes from photometry to feed models of stellar activity in exoplanet RV surveys (Geneva)

16:30-16:45 K. Hay: How should limb darkening be constrained when fitting exoplanet system parameters from a transit? (St Andrews)

16:45-17:00 T. North: Weighing in on the masses of retired A stars with asteroseismology. Ensemble Kepler and K2 observations of exoplanet hosts (Birmingham)

17:00-17:30 Poster pop-ups (chair: D. Forgan)

19:00 Conference Dinner & Ceilidh (Don't forget to bring your coloured ticket)

Friday 17th March 2017

Session V Discs and Planet Formation (Chair: P. Woitke)

09:00-09:15 K. Rice: Disc fragmentation rarely forms planetary-mass bodies (Edinburgh)

09:15-09:30 M. Fletcher: An implicit integration scheme for dust grains in PHANTOM (Leicester)

09:30-09:45 M. Davies: Survival of habitable planets in unstable planetary systems (Lund)

09:45-10:00 A. Mustill: What do outer worlds do to inner planets? (Lund)

10:00-10:15 G. Rosotti: The origin of the eccentricity of the hot-Jupiter in CI Tau (Cambridge)

10:15-10:30 M. Kama: Observational studies of the C and O abundance in protoplanetary discs (Cambridge)

10:30-10.45 D. Veras: Explaining transits and variability with tidal disruption simulations of minor planets (Warwick)

10:45-11:00 D. Forgan: Advanced population synthesis models of planet formation via disc instability (St Andrews)

11:00-11:30 Coffee

11:30-12:30 Discussion session presentation

12:30-14:00 Lunch

Session VI: Links to the Solar System (Chair: C. Helling)

14:00-14:15 S. Mikhail: How to make an Earth, and not a Venus (St Andrews)

14:15-14:30 G. Hodosán: Lightning on exoplanets and brown dwarfs: modelling lightning energies and radio powers (St Andrews)

14:30-14:45 P. Rimmer: Prebiotic Chemistry on Other Worlds (Cambridge)

14:45-15:00 Wrap-up by old and new UKEXOM hosts

15:00 Farewell coffee

List of posters

Daniel Apai: Results from the ACCESS Survey: The Largest Transmission Spectroscopy Survey of Exoplanets

Isabelle Baraffe: Improving stellar evolution models for exoplanet host stars: multi-dimensional fully compressible simulations of overshooting in solar like stars

Jean-Loup Baudino: How to benchmark and update models toward exoplanet characterisation with the JWST?

Claudia Belardi: Searching for Transiting Planets Around White Dwarfs: Kepler and Ground-based Observations.

Sarah Blumenthal: Detection of Disequilibrium Chemistry with JWST in Gaseous Planets

Mariangela Bonavita: Gravitational instability rarely forms wide, giant planets

Rachel Booth: An Improved Age-Activity Relationship for Cool Stars older than a Gigayear

Richard Booth: Planet formation in evolving discs: Juno and chemical constraints on the formation of Jupiter

David Brown: WASP-116 and WASP-149; two new discoveries from the SuperWASP survey

Ben Burningham: Atmospheric retrievals in the cloudy regime of free-floating planetary mass objects and directly imaged exoplanets

Mario Damiano: Spectroscopic observations of Hot-Jupiters with the Hubble WFC3 camera

Niall Deacon: Finding planets in extremely wide orbits

Giovanni Dipierro: Gap opening by planets in dusty protoplanetary discs

Benjamin Drummond: Exploring the Role of Metallicity: Unified Model Simulations of GJ 1214b

Daniel Evans: The effects of binary systems and contaminating light on transiting hot Jupiters

Tom Evans: Hot gas giant atmospheres: WASP-121b and the unknown role of TiO/VO

Fabo Feng: Agatha: disentangling periodic signals from correlated noise in a framework of periodograms

Mark Fletcher: An implicit integration scheme for dust grains in PHANTOM

Clemence Fontanive: Looking for Companions to Brown Dwarfs with the Novel Water

Band Detection Method

Siddharth Gandhi: Self-Consistent Models of Exoplanetary Spectra

Helen Giles: A Transit-Searching Pipeline for CHEOPS Candidates from Campaign 10 of K2

Jayesh Goyal: Exploring Exoplanet Atmospheres using Multi-Planet Model Grid.

Maximilian Guenther: The Next Generation Transit Survey: distinguishing planets from false positives

Cassandra Hall: Identifying and Analysing Protostellar Disc Fragments in Smoothed Particle Hydrodynamics Simulations

Paul Hallam: The role of gap edge instabilities in setting the depth of gaps in protoplanetary discs

Thomas Hands: Spontaneous breaking of mean-motion resonances during Type I planet migration

John Harrison: Polluted White Dwarfs: Insights regarding the chemistry of terrestrial exo-planets

Raphaëlle Haywood: Overcoming stellar activity noise in radial-velocity exoplanet surveys

Christiane Helling et al.: The Centre for Exoplanet Science at the University of St Andrews

Vedad Hodzic: Variable stars with the Next Generation Transit Survey

Matthew Hooton: Ground-based z' band secondary eclipse observations of WASP-103b

Robert Humphries: Accretion of Pebbles onto Gas Giant Planets at Wide Separations

Eric Hébrard: Chemical uncertainties in modelling hot Jupiters atmospheres: review and consequences

John Ilee: The chemical composition of protoplanets formed via gravitational instability

Kate Isaak: Observing with CHEOPS

James Jackman: Cross matching with the Next Generation Transit Survey

Hugh Jones: Ultrastable radial velocity spectrograph

George King: Multi-epoch observations of the HD 189733 system with XMM-Newton

James Kirk: Ground-based transmission spectroscopy of hot Jupiters using WHT/ACAM

Jessica Kirkby-Kent: Constraining helium abundances with precise binary parameters.

Kristine Lam: Ca II H & K absorption variation around WASP-12

Joe Llama: High energy exoplanet transits

Emma Longstaff: The irradiated atmopsheres of brown dwarfs

Ryan MacDonald: Peering Through The Clouds: Retrieving Properties of Transiting Exoplanet Atmospheres

Ryan MacDonald: HD 209458b in New Light: Detection of Nitrogen Chemistry, Patchy Clouds and Sub-Solar Water

Elisabeth Matthews: Direct Imaging of Wide Separation Planets and Scattered Light Debris Disks

Farzana Meru: Understanding the morphology of the protoplanetary disc, Elias 2-27

Giuseppe Morello: Blind extraction of exoplanetary spectra

Annelies Mortier: Stacking periodograms: tracking the significance of a periodic signal

Jonathan Nichols: Stellar wind-planet interactions: computing auroral radio emissions and observational testing of the Radiometric Bode's Law

Nikolay Nikolov: Radial Velocity Eclipse Mapping of Exoplanets

Charlotte Norris: 3D modelling of facular spectral contrasts.

Hugh Osborn: Machine learning with the WASP archive to detect long-duration deep eclipses

Mark Phillips: Developing a grid of cool brown dwarf atmospheres

Arazi Pinhas: Observable Signatures of Clouds in Exoplanetary Transit Spectra

Hall Richard: Measuring the Effective Pixel Positions of the HARPS3 CCD

Laura Rogers: Infrared Variability in Dusty White Dwarfs

Sarah Rugheimer: UV to IR Transits of Earth-like planets around FGKM stars

Nicole Schanche: Hunting for Planets in a Random Forest

David Sing: The Panchromatic Comparative Exoplanet Treasury Program

John Southworth: Current status of the TEPCat catalogue of transiting extrasolar planets

Craig Stark: Dust cloud evolution in substellar atmospheres via plasma deposition and plasma sputtering

John Strachan: High precision spectroscopic analysis of exoplanet transits using differential least-squares deconvolution

Lorna Temple: WASP-167b/KELT-13b: Joint Discovery of a Hot Jupiter Planet Orbiting a F1V Star

Jean Teyssandier: Orbital evolution during planet-disc interactions

Andrew Thompson: The changing face of ? Centauri B: probing plage and stellar activity in K dwarfs

Amaury Triaud: The TRAPPIST-1 system

Angelos Tsiaras: New tools for simulating and analysing HST / WFC3 spatial scans

Riccardo Vanon: Zonal flow evolution in discs

Alexander v. Boetticher: J0555-57, A TRAPPIST-I analog eclipsing F7 binary

David Wilson: The chemical composition of extrasolar planetesimals

Peter Woitke: Radiation Pressure on Dust Grains in Protoplanetary Discs

Jack Yates: Chemistry in the (Idealised) Unified Model Planet Simulator

Sergey Yurchenko: Spectroscopy of Hot Rocky Super-Earths

Sergey Yurchenko: Molecular line lists for exoplanet and other hot atmospheres

Tiziano Zingales: Generation of an optimal target list for ARIEL

Discussion session abstracts

Exoplanets: what can we learn from Earth?

Amy Bonsor & Oliver Shorttle (Institute of Astronomy, University of Cambridge)

Earth is the best studied planet we know. A century's work on terrestrial samples has interrogated 90% of its history, and revealed the physics of processes from the formation of the core to the rise of atmospheric oxygen. This detailed understanding can benefit our perspective of exo-planetary systems, whilst at the same time deepening our knowledge of Earth's formation. Profound questions still remain as to the origin of Earth's atmosphere, continents, and habitable climate, questions which are ultimately stymied by having only one natural laboratory in which to study these phenomena. As we enter an epoch where rocky exo-planets are regularly detected, it is critically important for Earth and exo-planetary sciences to come together to understand the geology of these new worlds, and in so doing learn more about the origin of our own. This break-out session will bring together members of the geology community (Dr. Oliver Shorttle) with the exo-planet community, to distil the key lessons learnt from studying Earth for current and future work on exo-planets. We will lead a discussion on the input the exo-planet community needs from the Earth Sciences community over the next two decades, addressing a series of key questions: How can we use our detailed understanding of Earth to target our search for rocky exo-planets? To what extent can observations constrain exo-planet compositions? How detectable are the characteristic signatures of Earth-like geological processes, such as plate tectonics, on exo-planets? How could we interpret atmospheric signatures in terms of geophysical processes?

Brown dwarfs as proxies for exoplanets

Sarah Casewell (University of Leicester)

It is often said that brown dwarfs are excellent proxies for exoplanets for a number of reasons: they have similar atmospheres; in the case of very young objects, they have similar masses; in close binaries they are irradiated; they show variability due to a dynamic atmosphere. In recent years, there have been attempts to bring together the exoplanet and brown dwarf communities, however the last major meeting was in 2013. Now, with a regular UK exoplanet meeting, the discussion session format is an excellent opportunity of bring together the two communities to discuss how observations and modelling may strengthen UK research in both fields. Indeed, many of the science teams for new missions due to launch over the next decades (e.g. JWST, ARIEL) are looking at brown dwarfs, as well as exoplanets as exciting targets. The format of this discussion is to be decided, however, it should consist of more discussion than formal talks. This session has support from: Joanna Barstow, Niall Deacon, Ben Burningham, Jonathan Nichols, Emma Longstaff, Beth Biller, Stefan Lines, Nathan Mayne, Ryan Garland, Duncan Forgan.

Discussion and Q&A: Stellar Activity in Exoplanet Surveys

Heather Cegla & Raphaëlle Haywood (University of Geneva, Harvard-Smithsonian Center for Astrophysics)

The main obstacle that we currently face in the detection and characterisation of small planets comes from the intrinsic variability of the host stars themselves. The UK hosts world-leading expertise in understanding the physical processes at play on stars and in developing solutions to enable the detection and characterisation of super-Earths and Earths. The aim of this session is to bring the community together to share both published and unpublished information, to dispel some common misconceptions and myths in the field and to initiate/strengthen collaborations amongst the UK community.

We propose an open Question & Answer session on stellar activity and its impact on exoplanet detection/confirmation and characterisation in radial-velocity and transit surveys, coupled with a short introduction session. Each participant will be encouraged to submit one presentation slide to introduce themselves and highlight any recent work at the start of the session. These presentations will last 1-3 min per person, depending on the number of participants, and this part will not exceed 20-30 min. We will include as many willing participants as possible, but PhD students and PostDocs will be given priority. For the remaining hour or so, we will lead a Q&A/discussion session.

Although we aim for this session to be an open discussion, we will prepare a list of relevant questions prior to the meeting, to encourage discussion, such as: which aspect of stellar activity is most hampering to exoplanet detection/confirmation/characterisation? How does activity on M dwarfs differ from FGK stars? Is the current observing strategy still the best for mitigating granulation noise and rotationally-modulated activity? Do the activity benefits outweigh the instrumentation difficulties in the IR? We will also highlight some common misconceptions, eg. the difference between faculae and plage, and the differences between 'activity', 'jitter', and 'noise'. We will also seek discussion ideas from the community prior to the meeting to ensure active discussions relevant to everyone in the session. This session will be extremely relevant to anybody wishing to detect, confirm and/or characterise exoplanets in the era of TESS, CHEOPS, INT/HARPS-3, JWST and soon VLT/ESPRESSO and PLATO.

Exoplanet Modelling

Nathan Mayne (University of Exeter)

Structure: this session will comprise two discussions one focused on terrestrial planet modeling and the other on gas giant modeling. Each session will be initiated by a short informal overview of the key challenges in this field by an expert (just a couple of slides). This will be followed by a discussion session where questions can either be contributed vocally, in real-time, or from preprepared submissions by participants. The questions will first be directed to an experienced academic (see Informal Panel), before being put to the participants, or vice–versa.

- Overview: Terrestrial Planet Modeling [$\sim$5 mins], Prof. R. Pierrehumbert
- Discussion: Terrestrial Planet Modeling [$\sim$35 mins] (questions alternating between real-time vocal (if available) and anonymous slides.
- Overview: Gas Giant Planet Modeling [$\sim$5 mins], Prof. I. Baraffe
- Discussion: Gas Giant Planet Modeling [$\sim$35 mins] (questions alternating between real-time vocal (if available) and anonymous slides.
- Summary From Session Chair: [$\sim$5 mins] I will attempt to collate the key questions/thoughts/plans of the room and present a couple of final slides to be approved by the participants before presenting to the rest of the conference/meeting on the final day.

Session Chair: N. Mayne

Informal Panel: Prof. I. Barraffe, Prof. P. Read, Prof. R. Pierrehumbert & Prof. C. Helling. The panel members will simply be available to provide thoughts/comments on questions during the discussion (i.e. not a traditional panel).

Layout/Requirements: if numbers permit the tables will be in a horseshoe arrangement, with a projector at the "open" end. Otherwise, if the session is too popular, we will shift to a circular, 'boardroom' meeting style, or in the extreme back to a traditional lecture hall style. In any case I do not want a traditional panel setup with people sat on the stage as I feel this encourages more of a Q&A style.

Participant Preparation: before attending each participant must submit questions as pdf slides (one slide per question, but more than one question is allowed per participant, email to nathan@astro.ex.ac.uk). These slides should be distinctive (visually, decorate as required), but will be anonymised. Attending delegates must be prepared, and unafraid, to share some of their views. This session is not supposed to be easy!

The disc-planet connection: from planet formation to planet observations

Farzana Meru (University of Cambridge)

We are entering an era in which a detailed understanding of planet properties are now possible. This will continue into the future with planet characterisation missions such as PLATO and CHEOPS. However these planets are observed long after their formation. How did they form and evolve into their current state? Planets could have formed either by core accretion or gravitational instability, following which a number of evolutionary processes can take place. How can we understand their formation and evolutionary histories from their observed properties? Some attempts aim to make this connection e.g. hot start and cold start models, as well as chemical constraints. We propose a discussion session that aims to brainstorm ways in which we can pin down signatures of particular formation and evolutionary processes. This session aims to make the connection between observers and theorists, as well as between those working on protoplanetary discs and planets.

Prospects to understand cloudy exoplanets.

Vivien Parmentier (University of Arizona)

Over a large range of equilibrium temperatures clouds seem to dominate the transmission spectrum of exoplanets atmospheres. Longitudinal and latitudinal variations in the cloud coverage is expected for these planets. The presence of such an inhomogeneous cloud coverage can bias the retrieved abundances from transmission and secondary eclipse spectra and even lead to erroneous molecular detections. Understanding the presence of clouds, their distribution and their chemical composition is a fundamental step to interpret future high quality JWST observations that can only be achieved by combining observations and theory. I propose a discussion summarizing the current effort and determining the directions to take towards a better understanding of cloudy exoplanets.

Laboratory Exoplanet Science

Paul Rimmer (University of Cambridge)

JUSTIFICATION: Exoplanets are like laboratories with very different conditions on which physics plays. Sometimes, though, our intuitions from established models are not enough to understand or explain our observations, and it is helpful to set up laboratory experiments to test out what these environments are like. Experiments have already been useful in planet formation by investigating how icy grains of different compositions stick or shatter when collided. Experiments already form a key component for generating molecular opacities used to model exoplanet atmospheres and confirm detections from exoplanet transmission and emission spectra. Laboratory experiments on bacteria in different environmental conditions can give us expansive insight into how life may interact on the very different environments of other worlds. I have talked with several exoplanet researchers, and many of them have ideas of experiments that they would like to run in order to answer key questions, but they don't know if these experiments are practical or who in the UK or Europe would have the necessary expertise to answer these questions and potentially to run these experiments. Often, when exoplanet researchers do contact experimentalists, the new perspectives can inspire useful insights for that experimenter as well as help address the exoplanet research question itself.
GOAL: The goal of this discussion group would be to get interested exoplanet scientists together, observers and modellers both, to list some experiments they would love to see performed, and to brainstorm together other useful projects for laboratory exoplanet research. The participants will then have a chance to follow up on these ideas after the conference and potentially build connections with interested relevant experimentalists within the UK and Europe.
STRUCTURE OF THE DISCUSSION: (20 min) Very short talks from 2-3 people about how laboratory experiments already take part within exoplanet science, for inspiration. Maybe include someone from ExoMol, one of the attending geologists, or someone working on astrobiology. (50 min) Breakout discussion (split to groups of 3-5 people each) which discuss amongst each other and compile lists of laboratory experiments they'd like to try (20 min) Come back together to combine the lists of experiments and then where possible to link experiments with potential experimentalists, focusing on those in the UK, but also in Europe

and USA. List places or people we might contact about these experiments. At the end of the meeting, each participant who wishes will put their name next to a particular experimental project, and will make a plan for for following up on this project.
FOLLOWUP: Those who sign their names next to a particular experiment will perform a literatures search on this list of experiments to see if they've been done before or if similar experiments have bene performed and by whom. They can then contact a relevant nearby lab and initiate conversation about this experiment. The best case will be that one or a few of these initial conversations will help initiate new experimental work, and could help to develop fledgling exoplanet laboratory research. It is likely that few or none of the experiments we come up with are practical and none will be run. But if the labs are interested in the ideas, this can build connections between experimental facilities and exoplanet groups. Exoplanet research, like planetary science before it, has already made great progress in both observation and in building useful simulations. This seems to be the key time for exoplanet research to develop more in the direction of experimental science.

Workshop on using the JWST simulator, PandExo

Sarah Rugheimer (University of St. Andrews)

In this discussion session we will talk about the prospects of observing Earth-like and terrestrial planets with JWST and steps to take to prepare for this upcoming mission. In the first half we will have a mini-splinter session of 10 min talks of researchers particularly discussing detection potential and limitations of characterizing terrestrial planets with JWST. The second half will be a panel and audience discussion with the splinter-session speakers as panellists for a more collaborative discussion with the audience on the feasibility to characterize other Earths and the community's next steps to prepare for the JWST era.

Talk abstracts

Extrasolar Storms: Cloud Physics and Atmospheric Dynamics in Brown Dwarfs and Exoplanets

Daniel Apai (The University of Arizona)

Observations of directly imaged and transiting exoplanets and brown dwarfs reveal the wide-spread presence of condensate clouds. These clouds profoundly influence the energy transport through ultracool atmospheres and impact their pressure-temperature profiles. Yet, the structure and properties of these cloud layers remain poorly understood and pose one of the great challenges to understanding ultracool atmospheres. I will show how a new observational approach allows us to address this challenge. With time-resolved spectroscopy and photometry - rotational phase mapping - we are exploring the longitudinal structure of clouds; with multiple epoch observations we are following the evolution of the cloud cover, opening a new window on atmospheric dynamics. With the powerful combination of simultaneous HST and Spitzer observations we are also exploring the vertical structure of the atmospheres, providing new constraints on cloud physics and atmospheric dynamics in brown dwarfs and directly imaged exoplanets.

The first detection of variability in a Hot Jupiter atmosphere

David Armstrong (University of Warwick)

The planets in our Solar System show a wide range of atmospheric phenomena, with stable wind patterns, changing storms, and evolving anomalies. Brown dwarfs also exhibit atmospheric variability. Such temporal variability in the atmosphere of a giant exoplanet has not to date been observed. HAT-P-7 b is an exoplanet with a known offset in the peak of its phase curve. I will present work published in Nature Astronomy showing that the peak offset varies between -0.086+0.033-0.033 to 0.143+0.040-0.037 in phase, implying that the peak brightness repeatedly shifts from one side of the planet's substellar point to the other. The variability occurs on a timescale of tens to hundreds of days. These shifts in brightness are indicative of variability in the planet's atmosphere, and result from a changing balance of thermal emission and reflected flux from the planet's dayside. I will suggest that variation in wind speed in the planetary atmosphere, leading to variable cloud coverage on the dayside and a changing energy balance, is capable of explaining the observed variation.

Discovering the youngest free-floating planets: a transformative survey of Taurus with the novel Wband filter

Beth Biller (University of Edinburgh)

Low mass brown dwarfs and free-floating planets in star-forming regions are vital tracers of the low mass end of the star-formation and key analogues to exoplanets around stars. However, only a handful of objects with masses below 13 MJup are known because they are difficult to distinguish from reddened background stars using traditional methods. An efficient method of searching for these young objects is to identify them via spectral features, such as the 1.45 um H2O absorption band seen in spectra of MLTY type objects. Allers & Liu 2010 pioneered this method with a 6% wide filter centered at 1.45 um for ULBCAM at the UH88' telescope, achieving a 90% spectroscopic confirmation rate. This filter is now decommissioned and, on a 2m class telescope, was only able to identify fairly bright candidates. We have acquired a 1.45 um filter with specifications appropriate to CFHT and have been using it with WIRCam to survey the Taurus star-forming region in order to detect the lowest mass components of this cluster.

Theia: a new astrometry mission to search for exoplanets.

Céline Boehm (Durham University)

Alessandro Sozzetti (INAF, Torino)

An overview on the proposed astrometry mission Theia.

The Compositional Diversity of Exo-planetary Material

Amy Bonsor (Institute of Astronomy, University of Cambridge)

White dwarfs that have been polluted with exo-planetary material provide a unique opportunity to study how diverse the composition of exo-planetary systems can be. This complements other techniques used to determine planetary composition including using mass-radii measurements and observations of exo-planet atmospheres. The observations of material accreted by white dwarfs illustrate a diversity in composition significantly larger than found, for example, in nearby stars. In this talk I discuss the origin of this diversity. I will compare and contrast with models for that aim to explain the difference in composition between the chondrites and Earth.

Exploring the climate of Proxima B with the Met Office Unified Model

Ian Boutle (Met Office)

We present results of simulations of the climate of the newly discovered planet Proxima Centauri B, performed using the Met Office Unified Model (UM). We examine the responses of both an 'Earth-like' atmosphere and simplified nitrogen and trace carbon dioxide atmosphere to the radiation likely received by Proxima Centauri B. Additionally, we explore the effects of orbital eccentricity on the planetary conditions using a range of eccentricities guided by the observational constraints. Overall, our results are in agreement with previous studies in suggesting Proxima Centauri B may well have surface temperatures conducive to the presence of liquid water. Moreover, we have expanded the parameter regime over which the planet may support liquid water to higher values of eccentricity (0.10) and lower incident fluxes (881.7 Wm-2) than previous work. This increased parameter space arises because of the low sensitivity of the planet to changes in stellar flux, a consequence of the stellar spectrum and orbital configuration. However, we also find interesting differences from previous simulations, such as cooler mean surface temperatures for the tidally-locked case. Finally, we have produced high resolution planetary emission and reflectance spectra, and highlight signatures of gases vital to the evolution of life on Earth (oxygen, ozone and carbon dioxide).

The CHEOPS transit photometry mission

Andrew Cameron (University of St Andrews)

CHEOPS (CHaracterising ExOPlanet Satellite) is the first S-(small) class mission in ESA's Science Programme and a partnership between ESA and Switzerland, with important contributions from 10 other member states including the UK. Over its 3.5 year lifetime (nominal, goal 5 years) CHEOPS will perform high-precision photometric monitoring of selected bright target stars from low-Earth orbit. Its 30-cm telescope will deliver sufficient precision to detect transits of earth-sized planets orbiting solar-type stars. It will search for transits by monitoring known radial-velocity planets at the times of inferior conjunction. It will provide precise radii for super-Earth and Neptune planets discovered by NGTS and the TESS satellite. It will also provide optical phase curves and precise transit timing for hot Jupiters. An ESA-managed Guest Observers' Programme will provide the Community with access to 20% of the available observing time on CHEOPS through a series of competitive calls for proposals.

The direct detection of an irradiated brown dwarf in an eclipsing binary

Sarah Casewell (University of Leicester)

Irradiated brown dwarfs are often used as proxies for exoplanets, particularly in systems where the primary is a white dwarf, providing high contrast ratios in the infrared, where the brown dwarf is brightest. To date, only 5 of these systems are known, however, and only one is eclipsing, providing the opportunity to observe the un-irradiated side of the brown dwarf. We have used NIR, high cadence lightcurves to directly detect the dark side of an irradiated brown dwarf in a close ($\sim$2 hrs) binary with a 13000 K white dwarf. This is the first time the dark side of a brown dwarf has been directly detected. The brown dwarf in this system is of a late spectral type (L7-T5), and there is a small reflection effect in the system, when compared to other irradiated brown dwarfs. I will discuss this system and provide comparisons to other irradiated brown dwarfs, putting our results into context, and explaining how this impacts the modelling of other irradiated bodies.

Cautionary Tales of Rossiter-McLaughlin Analyses

Heather Cegla (University of Geneva)

When a planet transits its host star, it obscures regions of the stellar surface and induces changes in the line-of-sight (LOS) velocities, known as the Rossiter-McLaughlin (RM) effect.

Since the observed velocities depend on the stellar rotation, the RM waveform is sensitive to the star-planet alignment (which provides information on the system's dynamical history). Traditional RM analyses assert that this velocity anomaly can be modelled under a few key assumptions: that the stellar surface is represented by homogenous Gaussian functions, and that rigid body stellar rotation is the sole contributor to the LOS velocities. However, these assumptions are inherently incorrect due to stellar surface magnetoconvection (and other manifestations of magnetic activity), and we have predicted that they can introduce systematic errors in sky-projected obliquities up to $\sim 20-30$ degrees (Cegla et al. 2016a). To obviate these assumptions, we developed the 'reloaded RM' technique to directly measure the spatially-resolved stellar spectrum behind the transiting planet (Cegla et al. 2016b). As proof-of-concept, we determined both the sky-projected (-0.4 +/- 0.2 degrees) and true 3D obliquity (7^{+12}_{-4} degrees) of HD 189733, as well as constrained its level of stellar differential rotational. More recently, we applied the reloaded RM to the highly misaligned WASP-8 system, and identified a variation of $\sim 35\%$ in the local photospheric profile contrast (from stellar equator to pole) that has hitherto gone undetected in classical RM techniques (Bourrier et al. 2017). Consequently, our results indicate the system is 20 degrees more misaligned than that reported by Queloz et al. 2010 (and also that the star is rotating 0.3-0.9 km/s faster). Hence, the reloaded RM provides a powerful tool to probe stellar photospheres, differential rotation, determine 3D obliquities, and remove sky-projection biases in planet migration theories.

Magnetic Exoplanets: Interacting Fields and Flows

Simon Daley-Yates (University of Birmingham)

We present Magnetohydrodynamic (MHD) simulations of the magnetic interactions between a solar type star and a short period hot Jupiter exoplanet using the publicly available MHD code PLUTO. The magnetic interactions between stars and their hosted exoplanets is a complex and challenging field of research, providing novel insights into planetary migration, angular momentum loss and stellar spin down via magnetic breaking. Previous work in this field has concentrated on ideal Hydrodynamic and MHD simulations of both the immediate surroundings of the exoplanet and the global evolution of the system. We build on this work by expanding to non-ideal MHD with the effects of resistivity. In our simulations, a planetary outflow, due to UV evaporation of the exoplanets atmosphere, results in the build-up of circumstellar and circumplanetary material. We analyse the behaviour of this material in the context of the magnetic topology. While recent theoretical studies have shown that an observational reduction in UV emission from these systems is not likely there is however the possibility of detecting emission due to magnetic interactions such as electron cyclotron emission.

Survival of habitable planets in unstable planetary systems

Melvyn Davies (Lund Observatory)

Many observed giant planets lie on eccentric orbits. Such orbits could be the result of strong scatterings with other giant planets. The same dynamical instability that produces these scatterings may also cause habitable planets in interior orbits to become ejected, destroyed, or be transported out of the habitable zone. I show how by measuring the orbital properties of any surviving gas giants, one may infer the likelyhood that the system contains habitable worlds.

Probing the emission spectra of two ultra-hot Jupiters using ground-based occultation photometry

Laetitia Delrez (University of Cambridge)

By observing the occultation (secondary eclipse) of a transiting exoplanet by its host star in the (near-)infrared, the thermal emission of its dayside can be retrieved. Using this technique at different wavelengths in the (near-)infrared allows to probe the emission spectrum of the planet's dayside, from which insights on the vertical thermal structure and chemical composition of its atmosphere can be gained. Very hot and inflated gas giants in very-short-period orbits around their stars are the most favorable targets for such measurements, thanks to their high temperature and large size. The atmospheres of such ultra-hot Jupiters are expected to be conducive for gaseous TiO and VO, which could cause thermal inversions (i.e. stratospheres) by reprocessing incident UV/visible irradiation to heat in the upper atmospheric layers. Thermal inversions have been previously claimed for several hot Jupiters based on Spitzer observations, but these results were recently found to suffer from significant systematic biases and were thus seriously called into question. Nevertheless, hottest planets are still the best candidates to host thermal inversions in their dayside atmospheres, the only planet showing clear evidence for a temperature inversion to date being WASP-33b, which is one of the most highly irradiated hot Jupiters currently known. In this talk, I will present results of an intense ground-based photometric campaign aiming at probing the emission spectra of WASP-103b and WASP-121b, two ultra-hot Jupiters orbiting their host stars just beyond the Roche limit.

An implicit integration scheme for dust grains in PHANTOM

Mark Fletcher (University of Leicester)

Since terrestrial like planets are made mainly of rocks, and gaseous giants contain massive solid cores, dust grains and solids in general must be key to the planet formation processes. Here we focus specifically on the gravitational disc instability model for formation of planets. We aim to improve numerical methods of dust grain dynamics employed in the widely used Smoothed Particle Hydrodynamics code Phantom. Phantom already implements two separate methods, one for treating dust particles strongly coupled to surrounding gas, and the other for particles coupled to gas moderately weakly. However, both of these regimes are simultaneously relevant to self-gravitating gas discs and clumps embedded in them. We present an approximate integration scheme that is able to cover both of these regimes provided that dust particle integration time step is sufficiently short compared with the SPH particle time steps. We present numerical tests of the code and preliminary applications to the problem of dust grain accretion onto massive gas clumps embedded in discs at tens of au from the host. We find that gas giant planets of a few Jupiter mass or less can become strongly metal over-abundant due to this process, provided a sufficient abundance of 0.1 cm or larger grains.

Advanced Population Synthesis Models of Planet Formation via Disc Instability

Duncan Forgan (University of St Andrews)

I will present recent results from our population synthesis modelling of planet and brown dwarf formation, which proceeds from the fragmentation of self-gravitating protostellar discs. We have upgraded these models in the light of 3D hydrodynamic simulations (Hall et al, submitted), which show that fragment-fragment interactions during the disc phase have profound consequences for fragment spin, internal structure and their ultimate fate - either to be fully bound substellar objects, or to be completely destroyed by tidal forces. Our upgraded population synthesis model now uses an N Body integrator to follow these interactions, as well as the drag forces exerted on the fragments by the disc. We will show that fragment eccentricities can be quickly pumped to high values, and indeed be ejected to form free floating planets. We will also demonstrate how our models can be compared with observations to constrain the (relatively low) frequency of disc fragmentation in the Milky Way.

Determining Starspot Lifetimes from Photometry to Feed Models of Stellar Activity in Exoplanet RV Surveys

Helen Giles (Université de Genève)

Since the first discovery of an extrasolar planet, crucial goals have included pushing down the size and mass of the planet and characterising them. For this, measuring the mass is most fundamental and achieved via RV observations. However, RV is heavily influenced by stellar activity which must be modelled with knowledge of known stellar processes. Kepler has produced reams of data suitable for investigating stellar activity of cooler stars. Starspot activity on these stars produces quasi-sinusoidal light curves whose phase and amplitude vary as active regions grow and decay over time. Using autocorrelation functions (ACFs) and Monte Carlo Markov Chains (MCMCs), we investigate whether there is a correlation between the size of starspots and their decay timescale, and if any correlation varies due to the effective stellar temperature. The results show such a correlation which depends heavily on the temperature of the star. Cooler stars have spots that last much longer, in particular for stars with longer rotational periods. This is consistent with current theories of diffusive mechanisms causing starspot decay and is an important stellar effect to be measured for determining planetary masses as well as further understanding of stellar physics.

Young transiting planets in the K2 clusters

Edward Gillen (University of Cambridge)

Co-authors: Josh Pepper, Hannu Parviainen, Lynne Hillenbrand, Suzanne Aigrain, Trevor David, John Stauffer, Keivan Stassun, Ann Marie Cody, Fred Vrba, Jorge Lillo-Box, Kyle Conroy, Benjamin Pope, David Barrado & Didier Queloz. Stars in young open clusters are valuable targets as exoplanet hosts, partly because clusters represent coeval populations with shared elemental composition, but also because they can be dated to a precision unattainable for field stars. Young planets in these clusters are particularly interesting as they offer a window onto the formation and early evolution of planetary systems. However, there are very few known planets in young clusters, making these of great interest for ongoing and future exoplanet searches such as Kepler/K2, TESS and PLATO. K2 has recently targeted five nearby young open clusters, spanning 1-800 Myrs. I will present our program to characterise young planets in the K2 clusters using our innovative Gaussian process regression techniques. I will focus on the discovery and characterisation of a small planet transiting an M dwarf member of the Praesepe open cluster through analysis of K2 observations, as well as follow-up ground-based photometry and high resolution spectroscopy. Finally, I will compare the known young K2 planets to the older Kepler sample, probing the evolution of planet size and orbital eccentricity.

Needle in a haystack: distinguishing planets from false positives with NGTS

Maximilian Guenther (University of Cambridge)

The Next Generation Transit Survey (NGTS) is a wide-field survey designed to detect Neptune-sized exoplanets, which has been operating in Paranal since early 2016. I will first introduce a new yield simulator, apply it to NGTS and discuss its outcome. Two major factors limit the survey: 1) the achieved red noise level, which determines the sensitivity to detect small planets, and 2) the ability to identify astrophysical false positives, which outnumber the planet yield. In particular, variable background objects (blended in the photometric aperture) can mimic Neptune-sized transits and are costly in follow-up time. They can best be identified with the centroiding technique: if the photometric flux is lost off-centre during an eclipse, the flux centroid shifts towards the centre of the target star. Although this method has successfully been employed by the Kepler mission, it has previously not been proven feasible from the ground. I will finally present a new algorithm I developed for NGTS that allows detecting centroid shifts with a precision of up to 1/1000th of a pixel. This makes NGTS the first ground-based transit survey ever to successfully implement this technique for candidate auto-vetting.

Modelling the climate of 55 Cancri e

Mark Hammond (University of Oxford)

Recent phase curve observations of the tidally locked 55 Cancri e have suggested the presence of a thick atmosphere capable of transporting considerable amounts of heat. The planet appears to have a strong temperature contrast between its day side and night side, although the nightside warmth and hot-spot position (60 degrees east of the substellar point) indicate effective heat transport by an atmosphere or a magma ocean. Transit depth observations tentatively suggest that the atmosphere may be hydrogen dominated. Thermodynamic calculations of outgassing from a silicate melt imply that appreciable amounts of sodium vapour should also be present in the atmosphere, though calculations specific to outgassing into a hydrogen atmosphere have not yet appeared. There are questions about whether a planet like 55 Cancri e can retain a hydrogen atmosphere, but the observations are sufficiently suggestive to warrant exploring the possible climates yielded by a hydrogen dominated atmosphere on this planet, with an eye to identifying possible observational signatures. We will

present results from a a 1D radiative-convective model to discuss the temperature profiles around the planet, and the possible effects of sodium as a condensable. We will also present results from a 3D GCM and discuss its fluid-dynamical and radiative features in relation to the observed temperature distribution - in particular the dayside-nightside temperature contrast and the phase shift of the hot spot relative to the substellar point.

How should limb darkening be constrained when fitting exoplanet system parameters from a transit?

Kirstin Hay (University of St Andrews)

When determining the parameters of an exoplanet system, the characteristics of the whole system (star and planet) contribute to the transit shape observed. Without taking into account the limb darkening of the host star appropriately, the planetary radius inferred from the transit shape will be biased. I will present a new method for sampling limb darkening to use in exoplanet transit fits. Observed stellar parameters are used as constraints for limb darkening and mapped onto a stellar intensity profile through the use of Gaussian processes and Artificial Neural Networks. This approach has particular use for low SNR transits, where fixing limb darkening or the use of lower order limb darkening laws can significantly bias the determined planetary radius. The applicability to the upcoming CHEOPS mission will also be demonstrated through fitting to simulated transit data.

Lightning on exoplanets and brown dwarfs: modelling lightning energies and radio powers

Gabriella Hodosán (University of St Andrews)

Lightning is a well studied though not fully understood phenomenon occurring not just on Earth but on other Solar System planets, such as Jupiter and Saturn, as well. Both observations and theoretical work suggest that the conditions in extrasolar planetary and brown dwarf atmospheres are good for lightning to occur. However, due to the lack of exo-lightning observations, we do not know how lightning in extrasolar atmospheres is similar or different from what is known from the Solar System. The aim of this study is to apply our knowledge of lightning production, derived mostly from Earth lightning, to the potential lightning discharge characteristics on extrasolar objects. In terms of observations, the power spectrum of lightning carries information regarding radiated power densities. From the total radiated power it is also possible to determine the energy dissipated from lightning discharges. However, modelling the power spectrum involves several steps and various parameters, including a characterization of the electric field. As such, we built a model and conducted a parameter study in order to explore the possible lightning powers and energies in different types of extrasolar atmospheres, such as giant planetary and brown dwarf atmospheres. We tested our model on Solar System cases based on previously published parameters in the literature, such as the duration of the discharge or the frequency at which the peak power is released. Our tests reproduce these published values for Earth, Jupiter and Saturn, and validate our model. When applying the model to extrasolar lightning discharges, we found that in giant gas planet atmospheres of $1500K < T_{eff} < 2000K$ and $\log(g) = 3.0$ the dissipation energy of lightning can reach as high as 10^{19} J, which is ten orders of magnitude larger than the average total energy of Earth lightning.

Exoplanet environments

Moira Jardine (University of St Andrews)

Review talk on exoplanet environments.

Planets around nearby M dwarfs

Hugh Jones (University of Hertfordshire)

Our current view of exoplanets is one derived primarily from Solar-like stars with a strong focus on understanding our Solar System. Knowledge about the properties of exoplanets around the dominant stellar population by number, the so called low-mass stars or M dwarfs is much more cursory. Based on combining radial velocities of nearby M dwarfs obtained with HARPS, UVES and HIRES we double the number of nearby M dwarf planets. By computing the estimated detection probability function for the sample and comparing and combining with findings from Kepler and microlensing studies the occurrence rate of planets around nearby M dwarfs is found to be at least three planet per star. Issues with recovering M dwarf planets are considered, for example: (1) the wavelength sensitivity of radial velocity signals, (2) the combination of radial velocity data from different experiments for robust detection of small amplitude signals and (3) selection of targets.

Observational studies of the C and O abundance in protoplanetary disks

Mihkel Kama (University of Cambridge)

The atmospheric C/O ratio is one of the few measurable properties of giant exoplanets. This ratio may be related to the formation conditions of a planet, offering a way of testing planet formation models and for mapping out planet formation histories. I will review recent results in measuring and understanding gas-phase volatile abundances in protoplanetary disks. I will focus particularly on the case of TW Hya and discuss how the observed abundances will allow to constrain models of physical processes in disks.

Modelling combined scattering and emission spectra using Monte Carlo radiative transfer

Graham Lee (University of St Andrews)

The 3D properties of exoplanet atmospheres are being observed in greater and greater detail. One of the main uncertainties of modelling 3D exoplanets is the radiative transfer through inhomogeneous, highly scattering cloud complexes. In this talk, we address this problem by presenting a Monte Carlo radiative transfer code and apply it to post-process the output of our 3D, cloud forming RHD/GCM model of HD 189733b. Our scheme is also able to capture a mix of Rayleigh and Mie scattering behaviour of a size distribution of cloud particles. We find that considering 3D geometric effects, cloud particle spatial inhomogeneity are important to the phase dependent properties of the exoplanet. We also present predictions of the albedo and phase curve properties of HD 189733b in the CHEOPS and TESS photometric bands.

Cloud formation and evolution in hot Jupiter atmospheres.

Stefan Lines (University of Exeter)

Recent HST observations of hot Jupiter atmospheres have revealed a continuum in atmospheric composition from cloudy to clear skies. The presence of clouds is inferred from a grey opacity in the near-IR that mutes key absorption features in the transmission spectra. This observational challenge inhibits the retrieval of key information including the atmospheric chemical composition and thermal structure. Unlike the L-T Brown Dwarf sequence, this transition does not correlate well with equilibrium temperature, suggesting that a cloud formation scheme more comprehensive than simply considering the condensation temperature needed for homogenous cloud growth, is required. In our work, we follow and extend the pioneering study of Lee et al., (2016) by performing 3D simulations of cloud nucleation, growth, advection, evaporation and gravitational settling in the atmospheres of HD209458b and HD189733b using the kinetic and mixed-grain cloud formation code DIHRT, coupled to the Met Office GCM, the 'Unified Model'. We explore cloud composition, vertical structure and particle sizes, as well as highlighting the importance of the strong atmospheric dynamics seen in tidally locked hot Jupiters on the evolution and distribution of the cloud. The completeness of the radiative transfer (i.e. inclusion of scattering) and the dynamics provided by our new model, will represent the most physically complete theoretical tool for the study of hot Jupiters.

Predictions for the Transition Between Rocky Super-Earths and Gaseous Sub-Neptunes

Eric Lopez (University of Edinburgh)

One of the most significant advances by NASA's Kepler Mission was the discovery of an abundant new population of highly irradiated planets with sizes between that of the Earth and Neptune, unlike anything found in the Solar System. Subsequent analysis showed that at 1.5 Earth Radii there is a transition from a population of predominantly rocky super-Earths to non-rocky sub-Neptunes, which must have substantial volatile envelopes to explain their low densities. Determining the origin of these highly irradiated rocky planets will be critical to our understanding of low-mass planet formation and the frequency of potentially habitable Earth-like planets. These short-period rocky super-Earths could simply be the stripped cores of sub-Neptunes, which have lost their envelopes due to atmospheric photo-evaporation or other processes, or they might instead be a separate population of inherently rocky planets, which never had significant envelopes. We suggest an observational path forward to distinguish between these scenarios. Using models of atmospheric photo-evaporation we show that if most bare rocky planets are the evaporated cores of sub-Neptunes then the transition radius should decrease as surveys push to longer orbital periods. On the other hand, if most rocky planets formed after their disks dissipate then these planets will have formed without initial gaseous envelopes. In this case, we use N-body simulations of planet formation to show that the transition radius should increase with orbital period. Moreover, we show that distinguishing between these two scenarios should be possible in coming years with radial velocity follow-up of planets found by TESS. Finally, we will discuss the broader implications of this work for current efforts to measure eta-Earth, which may yield significant overestimates if most rocky planets form as evaporated cores.

Modelling the phase curve and occultation of WASP-43b with SPIDERMAN

Tom Louden (University of Warwick)

Presenting SPIDERMAN, a fast code for calculating exoplanet phase curves and secondary eclipses with arbitrary two dimensional surface brightness distributions. SPIDERMAN uses an exact geometric algorithm to calculate the area of sub-regions of the planet that are occulted by the star, with no loss in numerical precision. The speed of this calculation makes it possible to run MCMCs to marginalise effectively over the underlying parameters controlling the brightness distribution of exoplanets. The code is fully open source and available over Github. We apply the code to the phase curve of WASP-43b using an analytical surface brightness distribution, and find an excellent fit to the data. We are able to place direct constraints on the physics of heat transport in the atmosphere, such as the ratio between advective and radiative timescales at different altitudes.

How to make an Earth, and not a Venus

Sami Mikhail (St Andrews)

To find solar systems hosting habitable exoplanets with similar geological and environmental conditions to Earth, we first must understand what it takes for an Earth-like planet to develop into an inhospitable wasteland. To this end, Earth and Venus are an ideal natural experiment. These two planets are colloquially referred to as sister planets because of their similar mass, bulk composition, and position in the solar system. However, their contrasting volcanology, atmospheric mass and chemistry, climate, and geomorphology are striking. Venus' hot (460 degrees Celsius) surface is flat and dry, while Earth's temperate (4 degrees Celsius) surface is mountainous and wet. Furthermore, the abundance of volcanoes on Earth dwarfs those on Venus by more than an order of magnitude – despite the fact that the Venusian planetary system must be the warmer of the two. We will outline an experimentally constrained and isotopically supported model that explains why volcanic activity on Venus is retarded when compared with Earth. In short, we find that the climate on Venus is so hot it inhibits volcanism and tectonism. The model we propose satisfies the overall flatness and relative dearth of volcanoes on the surface of Venus, and the isotopic composition of the Venusian atmosphere. We also find that the distance from the sun cannot solely account for the hotter Venusian climate, and in fact argue that if it were not for stochastic impact events, Earth's climate should be hundreds of degrees hotter and completely inhospitable to life.

What do outer worlds do to inner planets?

Alexander Mustill (Lund University)

I discuss my results presented in two recent papers (Mustill, Davies & Johansen 2015, ApJ; Mustill, Davies & Johansen 2016, MNRAS, submitted). These relate to the importance of the dynamical interactions between inner planetary systems (such as those observable by Kepler) and outer planetary systems. The first paper helps address the long-standing debate about the migration mechanism for hot Jupiters. I show that migration by eccentricity excitation (from planet-planet scattering or Kozai cycles) results in the destabilisation and destruction (usually by stellar collision) of any pre-existing inner planets. The lack of such companions to most hot Jupiters is therefore evidence in favour of high-eccentricity migration, while exceptions (such as WASP-47) must be disc-migrators. I then turn more generally to the effects dynamical excitation in the outer system can have on inner Kepler-detectable planets. I conduct N-body integrations of Kepler multi-planet systems with added giant planets and stellar binary companions in the outer system (¿1au). Some inner systems have their multiplicities reduced, or their mutual inclinations excited, providing some contribution to the "Kepler dichotomy" of an excess of single-planet systems. However, this dynamical excitation cannot be responsible for most of the dichotomy, suggesting that most of the systems of single Kepler-detectable planets attain their architecture as a result of earlier formation/migration processes.

VLT FORS2 comparative transmission spectral survey of clear and cloudy exoplanet atmospheres

Nikolay Nikolov (University of Exeter)

Thousands of transiting exoplanets are known today but not many have been studied in transmission. While observations with the Hubble Space Telescope (HST) have started to reveal a diversity of atmosphere types, drawing robust conclusions about the underlying population is hampered by the small sample size. This can be greatly aided by ground-based telescopes, equipped with multi-object spectrographs by their unprecedented access to the abundance of fainter systems that HST cannot observe. We have initiated a ground-based, multi-object transmission spectroscopy of a handful of hot gas-giants, covering the wavelength range 400-850nm, using the recently upgraded FOcal Reducer and Spectrograph (FORS2) mounted on the Very Large Telescope (VLT). These exoplanets were selected for a comparative follow-up as their transmission spectra showed evidence for alkali metal absorption, based on HST observations. This talk will discuss the results from the FORS2 program, that demonstrate an excellent agreement between the transmission spectra measured from VLT and HST and detections of Na and K absorption and scattering by clouds/hazes. Details will be presented on the narrow alkali features obtained with FORS2 at higher resolution, revealing its high potential in obtaining optical transmission spectra, which can greatly aid comparative exoplanet studies.

Weighing in on the masses of retired A stars with asteroseismology. Ensemble Kepler and K2 observations of exoplanet hosts

Thomas North (University of Birmingham)

Here we present the asteroseismic results for a series of evolved exoplanet hosts, observed in Campaigns 2-10 of the K2 Mission, allowing for a detailed asteroseismic analysis of the star. The higher accuracy and precision of asteroseismology provides masses consistent with the stars having been F or G type dwarf stars during their main sequence lifetimes, whilst literature values indicate an F or A type star, with literature masses derived from the fitting of spectroscopic parameters to isochrones. The lower masses from asteroseismology may provide a solution to the observed difference in mass distribution of exoplanet hosts between dwarf and evolved hosts, with the masses derived from isochrone fitting being overestimated, whilst asteroseismology recovers the true mass.

The early lives of low-mass planets' atmospheres

James Owen (Institute for Advanced Study, Princeton)

Many stars host low-mass planets in short orbital periods. A large number of these planets have low enough densities that they must have significant Hydrogen/Helium rich atmospheres. The presence of a Hydrogen/Helium atmosphere indicates that these planets must have formed before the gaseous protoplanetary disc dispersed. Observations of protoplanetary discs show that after a few million years they disperse rapidly on a considerably shorter timescale. I will argue that this dispersal phase has a dramatic impact on the atmospheres of close-in exoplanets, setting the stage for their later evolution and evaporation. The fast removal of the gaseous nebula which surrounds a young planet causes it to no longer be in thermal and dynamical equilibrium with its surroundings. To reestablish thermal and dynamical equilibrium with the now gas free interplanetary medium the planet's atmosphere cools by losing mass in a hydrodynamic outflow. I will argue this process, has a significant impact on setting the early properties of low-mass exoplanet's atmospheres such as their mass and entropy. In the most extreme cases, this early "boil-off" phase can remove up to 90% of the initially accreted atmosphere and increase its Kelvin-Helmholtz timescale by two orders of magnitude. Finally, I will discuss possible evidence in the observed exoplanet system Kepler-36 of a long Kelvin-Helmholtz timescale while it was young.

Cloudy nights on exoplanets

Vivien Parmentier (University of Arizona)

Over a large range of equilibrium temperatures clouds seem to dominate the transmission spectrum of exoplanets atmospheres but no trends allowing the classification of these objects have yet emerged. Recently, Kepler observations of the light reflected by hot Jupiters show that an inhomogeneous, asymetric and time-dependent cloud coverage is present in these planets. Interestingly, this asymmetry depends on the equilibrium temperature of the planet. Using state-of-the-art three dimensional models of hot Jupiters atmospheres I will show that longitudinal and latitudinal assymetry in the cloud coverage is expected for these hot planets. The presence of such an inhomogeneous cloud coverage can bias the retrieved abundances from transmission and secondary eclipse spectra and even lead to erroneous molecular detections. Cloudy nightsides further solves the apparent contradiction between models and observations, as cloudless models systematically underestimate the phase curve amplitude of hot Jupiters while overestimating the maximum offset. The longitudinal cloud asymetry being a strong function of the condensation temperature of the cloud species, it is a telltale of the cloud composition. Observations and models converge towards a similar conclusion: an L/T-like transition is expected for hot Jupiters, with silicate clouds disappearing from the cooler planets and being replaced by manganese sulfide clouds.

Dynamics of condensible-rich atmospheres on tide-locked exoplanets

Raymond Pierrehumbert (University of Oxford)

Water vapor is a dilute condensible on the present Earth, in the sense that it makes up only a small portion of the mass of the Earth's atmosphere. Situations with nondilute condensibles are expected to be common among the atmospheres of the smaller (Super-Earth and below) exoplanets, and would be generic both near the inner and outer edge of the conventional liquid-water habitable zone. We have developed a general circulation model and convection parameterization that can accurately handle nondilute dynamics. In previous work (http://rspa.royalsocietypublishing.org/content/472/2190/20160107) we presented results for rapidly rotating planets with a Earthlike instellation patterns. In this talk we will present results extending the work to tide-locked exoplanets, with particular emphasis on dayside/nightside contrast in composition. Implications for observations via spectrally resolved thermal emission phase curves and transit depth spectroscopy will be discussed. This talk is based on work conducted in collaboration with PhD student Feng Ding (U. of Chicago)

Disc fragmentation rarely forms planetary-mass bodies

Ken Rice (University of Edinburgh)

It is now reasonably clear that disc fragmentation can only operate in the outer parts of protostellar discs (r $>$ 50 au). It is also expected that any object that forms via disc fragmentation will have an initial mass greater than that of Jupiter. However, whether or not such a process actually operates, or can play a significant role in the formation of planetary-mass objects, is still unclear. We do have a few examples of directly imaged objects that may have formed in this way, but we have yet to constrain how often disc fragmentation may actually form such objects. What we want to consider here is whether or not we can constrain the likely population of planetary-mass objects formed via disc fragmentation by considering how a population of objects at large radii (a $>$ 50) au - if they do exist - would evolve under perturbations from more distant stellar companions. We find that there is a specific region of parameter space to which such objects would be scattered and show that the known exoplanets in that region have properties more consistent with that of the bulk exoplanet population, than with having been formed via disc fragmentation at large radii. Along with the scarcity of directly imaged objects at large radii, our results provide a similar, but independent, constraint on the frequency of objects formed via disc fragmentation.

Prebiotic Chemistry on Other Worlds

Paul Rimmer (University of Cambridge)

Several rocky planets have been discovered close enough to their host stars that it is likely liquid water can comfortably exist on their surfaces. The stars these planets orbit can be very different from the young Sun, and the planets' geological conditions and atmospheres may be very different from the geology and atmosphere of the Early Earth. It is useful to ask how likely it is for life to have started in these diverse environments, in order to select the most likely candidates for detecting signatures of life. Using prebiotic photochemical synthesis as our candidate theory, we show how the probability for life to originate on exoplanets depends critically on their atmospheric and surface compositions, their surface temperature and the stellar irradiation. We then show how this technique could be applied to a catalogue of liquid-water-habitable exoplanets to indicate on which presently detected candidates life is most likely to have originated. (Co-Authors: Samantha J. Thompson, Jianfeng Xu, Dougal Ritson, John D. Sutherland, Didier Queloz)

The origin of the eccentricity of the hot-Jupiter in CI Tau

Giovanni Rosotti (Institute of Astronomy, University of Cambridge)

CI Tau is the first star still possessing a protoplanetary disc where a radial velocity planet has been discovered. It is a hot Jupiter with a relatively high eccentricity ($e \sim 0.3$), which might be unexpected as in general discs are expected to damp eccentricity. I will show through long timescale (10^5 orbits) simulations that the planetary eccentricity can actually be pumped by the disc, even when its local surface density is well below the threshold previously derived from short timescale integrations. In particular for the system parameters of CI Tau I will show that the disc may be able to excite the planet's orbital eccentricity in less than a Myr. Therefore, at least in some cases it is possible to produce eccentric hot Jupiters purely by the interaction with the parent proto-planetary disc. Alternatively, the observed planet may plausibly have acquired its eccentricity through dynamical scattering of a migrating lower mass planet, which has either been ejected from the system or swallowed by the central star. In the latter case the present location and eccentricity of the observed planet can be recovered if it was previously stalled within the disc's magnetospheric cavity.

The Carbonate-Silicate Cycle on Earth-like Planets Near The End Of Their Habitable Lifetimes

Andrew Rushby (NASA Ames Research Center)

The terrestrial cycle of silicate weathering and metamorphic outgassing buffers atmospheric CO2 and global climate over geological time on Earth. To first order, the operation of this cycle is assumed to occur on Earth-like planets that exhibit similar continent/ocean configurations across the galaxy and has important implications for studies of planetary habitability. Here, we present results from a simple biogeochemical carbon cycle model developed to investigate the dynamics of the carbonate-silicate cycle under conditions of differing planet radius and position within the radiative habitable zone. Our findings suggest that the carbonate-silicate cycle strongly buffers planetary climate, extending the length of a planet's habitable period. However, the breakdown of the negative feedback between temperature, pCO2 and weathering rates towards the end of a planet's habitable lifespan results in a regime of 'carbon starvation' that would inhibit the ability of photosynthesizers to metabolize and result in the collapse of any putative biosphere supported by these organisms, suggesting an earlier limit for the initiation of inhabitable conditions than when considering temperature alone.

Spectroscopic phase curves of hot Jupiters

Jessica Spake (University of Exeter)

Phase curves of hot Jupiters provide a wealth of information about the dynamics of planetary atmospheres, enabling us to constrain the thermal structure and chemical abundances as a function of longitude. So far, only one spectroscopic phase curve has been published to date (Stevenson et al. 2014). We will present spectroscopic phase curve observations of one of the hottest exoplanets discovered, measured with HST's WFC3. We are able to probe deep into the atmosphere, to pressures up to 0.4 bar, and constrain the extremely high speed winds and large hotspot shift.

HARPS3 and the Terra Hunting Experiment

Samantha Thompson (University of Cambridge)

By mid-2019 we expect to be starting a 10-year survey to find Earth-like exoplanets around a select sample of our nearest G and K-type dwarf stars: this 10-year search is called the Terra Hunting Experiment. To enable this programme we are currently building HARPS3, a close copy of the HARPS and HARPS-N high stability Echelle spectrographs. HARPS3, like its predecessors, will be high resolution (R = 115,000) and span a wavelength range of 380-690nm. The blue end encompasses the Ca H and K lines to help monitor stellar activity. HARPS3 will also include a full Stokes dual-beam polarimeter enabling spectropolarimetric studies and also providing another means to track stellar activity. To help towards our aim of detecting an RV signal at the 10 cm/s level, HARPS3 will include an improved continuous-flow cryostat for increased CCD temperature stability and a pixel mapping of the CCD to improve the wavelength solution. The instrument will also be run in a robotic operation enabling the efficient and optimised collection of long, regularly sampled time-series RV data. HARPS3 will be installed on the 2.5m Isaac Newton Telescope in La Palma, which will be upgraded to robotic operations for this programme. We present a description of the programme and an update on the current status.

ARIEL – Atmospheric Remote-Sensing Infrared Exoplanet Large-survey

Giovanna Tinetti (UCL)

ARIEL is one of the medium class mission candidates in the Cosmic Vision programme of the European Space Agency (ESA) to be launched in the 2026 timeframe. The selection of one of the three mission candidates is foreseen for June 2017. The goal of the ARIEL mission is to investigate the atmospheres of a large population of planets orbiting distant stars in order to address the fundamental questions on how planetary systems form and evolve. During its four (with a potential extension to six) years mission ARIEL will observe ~ 1000 exoplanets in the visible and the infrared with its meter-class telescope in L2. ARIEL targets will include Jupiter- and Neptune-size down to super- Earth and Earth-size around different types of stars. The main focus of the mission will be on hot and warm planets orbiting very close to their star, as they represent a natural laboratory in which to study the chemistry and formation of exoplanets. The ARIEL mission concept has been developed by a consortium of more than 50 institutes from 12 countries, which include UK, France, Italy, Germany, the Netherlands, Poland, Spain, Belgium, Austria, Denmark, Ireland and Portugal. 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 favorable targets. It will also enable the study of thermal and scattering properties of the atmosphere as the planet orbit around the star. ARIEL will have an open data policy, enabling rapid access by the general community to the high-quality exoplanet spectra that the core survey will deliver.

A septet of earths in the TRAPPIST-1 system

Amaury Triaud (University of Cambridge)

Understanding the astronomical requirements for life to emerge, and to persist, on a planet is one of the most important and exciting scientific endeavours, yet without empirical answers. To resolve this, multiple planets whose sizes and surface temperatures are similar to the Earth, need to be discovered. Those planets also need to possess properties enabling detailed atmospheric characterisation with forthcoming facilities, from which chemical traces produced by biological activity can in principle be identified. I will report the results of an intensive ground and space-based photometric monitoring of TRAPPIST-1. Our observations reveal that at least seven planets revolve around TRAPPIST-1. We measured their radii and obtained first estimates of their masses thanks to transit timing variations. The incident flux on the planets ranges from Mercury to Ceres, comprising the Earth, and permitting climatic comparisons between each of those worlds such as is not possible within our Solar system. All seven planets could harbour liquid water on at least a fraction of their surfaces, given some atmospheric and geological conditions.

Explaining transits and variability with tidal disruption simulations of minor planets

Dimitri Veras (University of Warwick)

Evaporating and disintegrating planets provide unique insights into chemical makeup and physical constraints. The striking variability, depth ($\sim 10 - 60\%$) and shape of the photometric transit curves due to the minor planet orbiting white dwarf WD 1145+017 has galvanised the post-main-sequence planetary science community. We performed the first tidal disruption simulations of this planetary object, and have succeeded in constraining its mass, density, eccentricity and physical nature. We illustrate how our simulations can bound these properties, and be used in the future for other exoplanetary systems.

Deep learning in exoplanet spectroscopy

Ingo Waldmann (UCL)

The field of exoplanetary spectroscopy is as fast moving as it is new. Analysing currently available observations of exoplanetary atmospheres often invoke large and correlated parameter spaces that can be difficult to map or constrain. This is true for both: the data analysis of observations as well as the theoretical modelling of their atmospheres. Issues of low signal-to-noise data and large, non-linear parameter spaces are nothing new and commonly found in many fields of engineering and the physical sciences. Recent years have seen vast improvements in statistical data analysis and machine learning that have revolutionised fields as diverse as telecommunication, pattern recognition, medical physics and cosmology. In this talk I will discuss how these improvements in machine learning can be applied to planetary, exoplanetary and brown-dwarf spectroscopy. Here, deep learning can be a powerful tool to not only classify large data-bases of spectra efficiently but also to provide optimal data-cleaning algorithms that adapt to data and learn from experience.

Poster abstracts

Results from the ACCESS Survey: The Largest Transmission Spectroscopy Survey of Exoplanets

Daniel Apai (The University of Arizona)

I will present an overview of the ACCESS Exoplanet Transit Spectroscopy survey, which is using the 6.5m Magellan telescope and its IMACS multi-object spectrograph to build up the largest and most homogeneous optical transit spectroscopy survey of exoplanets. With observations of more than 40 transits our library covers objects ranging from super-earths to inflated hot jupiters; thanks to the large aperture telescope and the well-understood systematics our observations can yield precision better than HST/STIS spectroscopy and also reach fainter targets. I will show example results from our campaign.

Improving stellar evolution models for exoplanet host stars: multi-dimensional fully compressible simulations of overshooting in solar like stars

Isabelle Baraffe (University of Exeter)

Overshooting process in stellar interiors drives the transport of chemical species and of heat, impacting the structure and evolution of many types of stars. The treatment of this process is a fundamental uncertainty in stellar evolution calculations. Quantifying the extent of mixing at convective boundaries is key because it can dramatically affect the size of a convective core, the lifetime of major burning phases or the surface chemistry for a wide range of stellar masses. I will present new results based on the development of multi-dimensional, fully compressible, hydrodynamical, time implicit simulations with realistic stellar input physics of envelope overshooting in pre-Main sequence stars. We show the existence of extreme events of intermittent convective plumes that penetrate much further away from the convective boundary in the stable radiative region than the average plume. Applying extreme value theory to statistically analyse the results, we derive a new form for the diffusion coefficient describing the overshooting mixing. I will discuss the impact of these new results on 1D stellar evolution models that are so crucial to characterise the properties of exoplanet host stars.

How to benchmark and update models toward exoplanet characterisation with the JWST?

Jean-Loup Baudino (University of Oxford)

In October 2018 the JWST will be launched with four instruments on board. Thanks to its large collecting area (25 m2, 50 times larger than Spitzer), JWST will be a key facility to study exoplanetary atmospheres, especially in the MIRI wavelength range, rich in molecular and dust features, and so far barely explored. Indeed, only a couple of spectra of transiting exoplanets have been collected in this wavelength range and none for exoplanets detected by direct imaging. Many atmospheric models are available in the literature, which they will be used to analyse these observations. To ensure the best possible analysis, we propose to analyse spectra and profiles of benchmark cases with a number of different radiative transfer and retrieval tools, such as NEMESIS. With this work we will be able to identify differences between models and else to update them. We also highlight some crucial unknowns in the atmospheric and radiative transfer assumptions that need to be more fully understood and carefully treated by modellers.

Searching for Transiting Planets Around White Dwarfs: Kepler and Ground-based Observations.

Claudia Belardi (University of Leicester)

White dwarfs are the most common type of stellar remnant in our Galaxy. A fraction of these objects has been observed to host debris disks and planetary remnants, which is an indication that planets may also orbit them. Here, we present some results from our extensive search for transits around white dwarfs in data from the Kepler K2 mission, and from ground-based surveys and targeted campaigns.

Detection of Disequilibrium Chemistry with JWST in Gaseous Planets

Sarah Blumenthal (University of Exeter)

We investigate the impact of disequilibrium chemistry effects on the dayside emission spectra for three prospective targets for the James Webb Space Telescope: HD189733b, WASP-80b, and GJ436b. These planets span over the range of parameters potentially observable with JWST: hot, Jupiter-sized to cooler, Neptune-sized planets. We use (1) a one-dimensional disequilibrium chemistry model in which thermochemical kinetics, vertical transport, and photochemistry are taken into account, (2) PyratBay, a one-dimensional, line-by-line radiative transfer model developed especially for hot Jupiters using lines from both HITRAN and HITEMP, and (3) the PandExo JWST simulator. We consider the opacities of 16 relevant molecules for H, C, N, and O, as well as H2-H2 and H2-He collision-induced absorptions. We explore the consequences of upper atmospheric heating and different metallicities on simulated JWST dayside emission spectra, in the light of different signal-to-noise ratios and observational modes. We find the most significant differences due to disequilibrium chemistry to be detectable from 4 to 5 microns with the Near Infrared Spectrograph (NIRSpec) Grism 395. We also find noticeable differences beyond 10 microns. However, without a straight-forward spectral mode on the Mid-Infrared Instrument (MIRI), we cannot yet disentangle these effects.

Gravitational instability rarely forms wide, giant planets

Mariangela Bonavita (University of Edinburgh)

Understanding the formation and evolution of giant planets (>1 MJup) at wide orbital sep-

aration (>5 AU) is one of the goals of direct imaging. Over the past 15 years, many surveys have placed strong constraints on the occurrence rate of wide-orbit giants, mostly based on non-detections, but very few have tried to make a direct link with planet formation theories. In this talk I will present the result coming from the statistical analysis of a sample resulting from the combination of some of the biggest Direct Imaging surveys published to date, including the recent VLT/NaCo large program. The aim of the analysis is to both constrain the frequency of giant planets in wide orbit and to compare such results with the predictions of state-of-the-art population synthesis models based on the gravitational instability (GI) formation scenario. I will then finally show preliminary results of the application of the method to the sample observed within the SHINE survey which is currently ongoing as GTO program for SPHERE, the new VLT planet finder which has been in operation for the last 2 years.

An Improved Age-Activity Relationship for Cool Stars older than a Gigayear

Rachel Booth (Queen's University Belfast)

Magnetic activity is crucial to the understanding of the potential habitability of exoplanets. The strong radiation (particularly in the X-ray and ultra-violet wavelengths) emitted by a star can cause atmospheric mass loss from the exoplanet. Therefore, it is important to understand magnetic activity and its evolution with time. For solar-type and late-type stars it is known that they spin down over time due to magnetic braking, which has led to many studies concerning the evolution of stellar rotation and stellar activity with age. The majority of these studies construct a relationship that is only reliable for ages younger than a gigayear due to the difficulty of determining ages for older stars. However, recent observational advancements have made it possible to study ages for a larger sample of stars through asteroseismology; opening up the possibility of stellar age investigations for stars older than a gigayear. My research uses ages determined from asteroseismology coupled with X-ray observations to derive a new and improved age-activity relationship for cool stars older than a gigayear.

Planet formation in evolving discs: Juno and chemical constraints on the formation of Jupiter

Richard Booth (Institue of Astronomy, Cambridge)

Terrestrial planet formation models typically require the giant planets to have formed early on in the solar system's history, but how they formed remains a mystery. Traditional core accretion models fail to produce planetary cores that are massive enough to accrete their gaseous envelopes before the disc disperses. Recently, it has been shown that giant planet cores may grow rapidly by accreting pebbles rather km-sized planetesimals, thus reaching the mass required for gas accretion. However, these pebbles also drift rapidly towards the central star, driving physical and chemical evolution of the parent protoplanetary disc. We demonstrate that this evolution leaves a clear chemical imprint in the abundances of giant planet atmospheres. Applying these models Jupiter, we see that Jupiter must have formed inside the CO snow line and that its C/O ratio should be greater than the solar value. Thus Juno's measurements of Jupiter's abundances can be used to constrain giant planet formation via pebble accretion in the immediate future.

WASP-116 and WASP-149; two new discoveries from the SuperWASP survey

David Brown (University of Warwick)

The SuperWASP survey is the most successful ground-based transit search to date, and continues to discover new exoplanets covering a wide range of parameter space. Here we present two new SuperWASP planets, WASP-116 and WASP-149. Using a combined analysis of photometric lightcurves and radial velocity observations, we determine key orbital and physical parameters for the these planetary systems. The two planets have contrasting physical and orbital parameters that place them in different physical environments, and in different regions of parameter space.

Atmospheric retrievals in the cloudy regime of free-floating planetary mass objects and directly imaged exoplanets

Ben Burningham (University of Hertfordshire)

Spectral retrieval of atmospheric parameters such as temperature profiles and gas mixing ratios provides an superb opportunity to test and improve grid based forward models in a way that simple model fitting of substellar spectra cannot offer. Originally developed for analysis of reflection and emission spectra of solar system bodies, and adapted for transit spectra of exoplanets, recently significant progress has been made adapting these methods for emission spectra of cool brown dwarfs and self-luminious exoplanets. Retrieving atmospheric parameters of directly imaged exoplanets and young isolated planetary mass objects presents a number of challenges, chief of which is the likely presence of thick clouds. Clouds can obscure the deeper atmosphere and create degeneracies between cloud properties and the thermal profile, and the retrieved abundances of certain key absorbers. In this contribution I will outline the latest results of an effort to construct a framework for coping with these challenges, exploring cases of L dwarfs across a range of gravities and metallicities, using both simple grey cloud approximations and more sophisticated retrievals aimed at accounting for the scattering properties of expected condensates.

Spectroscopic observations of Hot-Jupiters with the Hubble WFC3 camera

Mario Damiano (UCL / INAF)

Thousands of exoplanets have been discovered with a huge range of masses, sizes and orbits. The next step to characterize them is to study their atmosphere. The atmospheres of giant planets are mostly made of hydrogen and helium. The relevant questions therefore concern the amounts of all elements other than hydrogen and helium, i.e. the heavy elements, that are present. The atmospheres of hot Jupiters present a critical advantage compared to the planets of the Solar System: their high temperature. Unlike Jupiter and Saturn, there is no cold trap in their atmosphere for species such as H2O, CH4, NH3, CO2 etc., which condense at much colder temperatures. Observations of hot gaseous exoplanets can therefore provide a unique access to their elementary composition (especially C, O, N, S) and enable the understanding of the early stage of planetary and atmospheric formation during the nebular phase and the following few millions years. In this environment Hubble Space Telescope has been a key instrument to start achieving some common behaviour among Hot Jupiters. Here, I present new spectroscopic observations of hot-Jupiters' atmospheres obtained with the WFC3 camera. In this presentation I will focus on the data reduction method used and on the interpretation of the results through state of the art spectral retrieval models.

Finding planets in extremely wide orbits

Niall Deacon (University of Hertfordshire)

This decade has seen the identification of the first gas giant planets in extremely wide orbits. These present a challenge both to planet formation models and to the traditional planet/brown dwarf boundary. I will discuss, 2MASS 2126, previously thought to be a free-floating planet but discovered last year to be a companion to a young star on the planet/brown dwarf boundary and in a wider orbit than any known planet. I will also outline our search for wide, cold planets in the solar neighbourhood using Spitzer imaging.

Gap opening by planets in dusty protoplanetary discs

Giovanni Dipierro (University of Milan)

Recent spectacular spatially resolved observations of gaps and ring-like structures in nearby dusty protoplanetary discs have revived interest in studying gap-opening mechanisms. In this talk I'll describe the two distinct physical mechanisms for dust gap opening by embedded planets in protoplanetary discs: I) A mechanism where low mass planets, that do not disturb the gas, open gaps in dust by tidal torques assisted by drag in the inner disc, but resisted by drag in the outer disc; and II) The usual, drag assisted, mechanism where higher mass planets create pressure maxima in the gas disc which the drag torque then acts to evacuate further in the dust. Starting from these numerical evidences, we derive a grain size-dependent criterion for dust gap opening in viscous protoplanetary discs by revisiting the theory of dust drift to include disc-planet tidal interactions and viscous forces. We finally apply our findings to the case of the HL Tau protoplanetary discs. We perform global, three dimensional dusty smoothed particle hydrodynamics calculations of multiple planets embedded in dust/gas discs which successfully reproduce most of the structures seen in the ALMA image. We find a best match to the observations using three embedded planets with masses of 0.08, 0.1 and 0.5 $M_{\rm J}$ in the three main gaps observed by ALMA, though there remain uncertainties in the exact planet masses from the disc model.

Exploring the Role of Metallicity: Unified Model Simulations of GJ 1214b

Benjamin Drummond (University of Exeter)

I will present results from a new chemical scheme coupled to the Met Office Unified Model (UM), a three-dimensional atmosphere model. We have recently incorporated a Gibbs energy minimisation scheme to the UM, greatly increasing the flexibility of the model allowing us to simulate atmospheres with a wide-range of compositions. Together with the sophisticated radiative transfer module (Amundsen et al., A&A, 2016) this allows for the accurate calculation of the heating rates, across for a large number of chemical regimes. In the first application, we have investigated the impact of varying the metallicity on the dynamic and thermodynamic structure of the atmosphere of GJ 1214b, a super Earth-type exoplanet. Overall, we find that as the metallicity is increased, the typical wind velocities and temperatures are also increased, with impacts on the emission of the atmosphere. I will also present preliminary results of a new development which couples a chemical kinetics scheme to the UM, with application to the wind-driven advection of important chemical species (e.g. CH4), particularly relevant for atmospheres with large day-night temperature contrasts.

The effects of binary systems and contaminating light on transiting hot Jupiters

Daniel Evans (Keele University)

Binary stars undoubtedly play a role in the formation and evolution of hot Jupiters. However, until recently the binary properties of hot Jupiter host stars have not been studied in detail, leaving theoretical predictions untested. In addition, contaminating light from nearby stellar sources will cause systematic errors when studying the planet and its host star – transits, radial velocity measurements, and transmission spectroscopy are all affected, especially in the near infrared where low mass stellar companions appear brighter. I present the results of the ongoing High-resolution Imaging of Transiting Extrasolar Planetary systems (HITEP) survey, which is systematically searching for stellar companions using both lucky imaging and adaptive optics. I discuss our conclusions on the multiplicity fraction of hot Jupiters. Some detailed case studies are also presented, including the effect of WASP-103's faint companion on transmission photometry, and the discovery that the WASP-20 system consists of two bright stars separated by only a quarter of an arcsecond.

Hot gas giant atmospheres: WASP-121b and the unknown role of TiO/VO

Tom Evans (University of Exeter)

Transmission and emission spectroscopy observations allow us to probe the compositional makeup of transiting exoplanet atmospheres. Hot gas giants are ideal targets for such observations due to their extended atmospheric scale heights, strong absorption features, and frequent transits. Measured transmission spectra to date have revealed a diversity of atmosphere types ranging from clear to cloudy, although the chemistry and physics of the putative aerosols remain largely unknown. Thermal emission measurements also hint at a distinction between atmospheres with a thermal inversion (stratosphere) and those without, although the cause of these differences is not yet understood. One possibility is high-altitude absorption by gaseous TiO and VO, species that are known to be important absorbers in the atmospheres of M/L dwarfs. To date, however, TiO/VO has not been securely detected in a planetary atmosphere, despite numerous searches. In this context, I will present HST observations for the ultra-hot (∼2500K) gas giant WASP-121b showing new evidence for absorption by TiO/VO.

Agatha: disentangling periodic signals from correlated noise in a framework of periodograms

Fabo Feng (Centre for Astrophysics Research, University of Hertfordshire)

One of the main challenges of detecting Earth-sized planets using radial velocity technique is to disentangle Keplerian signals from correlated noise. We introduce a framework of periodograms, called "Agatha", to disentangle periodic signals from correlated noise and to solve the 2-dimensional model selection problem: signal detection and noise model subtraction. Agatha is based on periodograms calculated by applying likelihood maximization and marginalization semi-numerically. Compared with other periodograms, Agatha is able to select the best noise model, to account for time-and- wavelength-dependent noise using various noise proxies, and to test the consistency of signals in time using a 2D periodogram. Using Agatha in combination with Bayesian methods, we find one super Earth orbiting HD41248 and a Neptune-like candidate orbiting HD177565. Agatha is general and flexible enough to be applied to time series analysis in other astronomical and scientific disciplines.

An implicit integration scheme for dust grains in PHANTOM

Mark Fletcher (University of Leicester)

Since terrestrial like planets are made mainly of rocks, and gaseous giants contain massive solid cores, dust grains and solids in general must be key to the planet formation processes. Here we focus specifically on the gravitational disc instability model for formation of planets. We aim to improve numerical methods of dust grain dynamics employed in the widely used Smoothed Particle Hydrodynamics code Phantom. Phantom already implements two separate methods, one for treating dust particles strongly coupled to surrounding gas, and the other for particles coupled to gas moderately weakly. However, both of these regimes are simultaneously relevant to self-gravitating gas discs and clumps embedded in them. We present an approximate integration scheme that is able to cover both of these regimes provided that dust particle integration time step is sufficiently short compared with the SPH particle time steps. We present numerical tests of the code and preliminary applications to the problem of dust grain accretion onto massive gas clumps embedded in discs at tens of au from the host. We find that gas giant planets of a few Jupiter mass or less can become strongly metal over-abundant due to this process, provided a sufficient abundance of 0.1 cm or larger grains.

Looking for Companions to Brown Dwarfs with the Novel Water Band Detection Method

Clemence Fontanive (University of Edinburgh)

The binary properties of old brown dwarfs are thought to be substantially different than in young clusters. Confirming these trends is essential to understand their origins, which will provide serious constraints to formation and evolution models. A common problem encountered in direct imaging searches for brown dwarfs is the high contamination rate observed in most photometric surveys. True brown dwarfs may however be distinguished from background stars through the water absorption feature robustly observed at 1.4 um in substellar objects. The WFC3/IR F139M filter on HST is sensitive to this water absorption band. Combined with the F127M filter, this bandpass provides a unique probe into this substellar characteristic, offering a very robust detection method for brown dwarfs. Using this new technique, we have searched for companions to very young brown dwarfs as well as objects from the field population. In this talk I will present the preliminary results of this survey, aimed at constraining the substellar multiplicity properties at different ages. Two planetary-mass candidate companions were identified in our young sample and are presented here. If confirmed, these candidates would significantly increase the census of very low-mass companions around extremely young brown dwarfs.

Self-Consistent Models of Exoplanetary Spectra

Siddharth Gandhi (Institute of Astronomy)

We are entering the era of high-precision and high-resolution spectroscopy of exoplanets. Such observations herald the need for robust self-consistent spectral models of exoplanetary atmospheres to investigate intricate atmospheric processes and to make observable predictions. I will talk about our new plane-parallel, line-by-line atmospheric modelling code GENESIS that is a step in this direction, using the most stable numerical techniques and latest opacity data. We model atmospheric profiles and emergent spectra of giant atmospheres over a range of equilibrium temperatures, metallicities, and irradiation regimes, spanning irradiated vs non-irradiated planets, and irradiated planets with and without thermal inversions. We also report models of several known hot Jupiters. I will discuss the implications of the results and future work in light of state-of-the- art needs of the field.

A Transit-Searching Pipeline for CHEOPS Candidates from Campaign 10 of K2

Helen Giles (Université de Genève)

The K2 mission provides one of the most valuable sources of targets for CHEOPS, with its ecliptic fields perfectly matched to CHEOPS observability. However, with the sheer volume of data and the range of possible transits, we need to create a pipeline which analyses all targets and puts forward the best candidates. To do so, the pipeline automatically searches for transits using a Box-fitting Least Squares (BLS) routine which folds light curves at multiple trial periods and fits boxes of different lengths and depths. Then a light curve model is fitted to targets which appear to have possible transits, and will be run through a series of vetting procedures to attempt to rule out false positives. We apply this pipeline to the observed stars in Campaign 10, using light curves generated from four different reduction pipelines in an effort to catch all possible candidates. Additionally, we plan to measure masses for any planets transiting bright stars using the Coralie spectrograph on the 1.2m Euler telescope in Chile.

Exploring Exoplanet Atmospheres using Multi-Planet Model Grid.

Jayesh Goyal (University of Exeter)

Interpreting observations of exoplanet atmospheres require model spectra. I will present an analysis of a grid of forward model transmission spectra, for a subset of hot Jupiter exoplanets. I will discuss the range of atmospheres possible for a given planet, based on their characteristics like equilibrium temperature, metallicity, C/O-ratio, presence of optical haze and clouds, and their signatures in the transmission spectra. For example, atmospheres rich in alkali elements form at particular threshold temperatures, those with stratospheric inversions at very high temperatures due to TiO/VO, currently undetected HCN and H2S spectral features indicating high metallicity atmospheres and many such physical properties of planets. I will also talk about the application of this grid to observations of certain exoplanets (from Sing et al. 2016) and best fitting physical characteristics of these planets. The underlying grid has been developed using a sophisticated fully self-consistent 1D radiative convective equilibrium model ATMO (Tremblin et al. 2015, Amundsen et al. 2014, Drummond et al. 2016) with the most up-to date high temperature opacities (e.g., ExoMol). The total grid covers 120 hot Jupiter exoplanets which now includes 3360 isothermal transmission spectra per planet, and is currently being extended to include pressure-temperature profiles, equilibrium transmission spectra, emission spectra and contribution functions. This grid will be made publicly available, and for the first time will provide an extensive database to aid both the physical interpretation of observations, and the selection of the best targets for future observations.

The Next Generation Transit Survey: distinguishing planets from false positives

Maximilian Guenther (University of Cambridge)

The Next Generation Transit Survey (NGTS) is a wide-field survey designed to detect Neptune-sized exoplanets, which has been operating in Paranal since early 2016. We develop a new yield simulator, apply it to NGTS, and discuss the two major factors limiting the survey: 1) the achieved red noise level, which determines the sensitivity to detect small planets, and 2) the ability to identify astrophysical false positives, which outnumber the planet yield. In particular, variable background objects (blended in the photometric aperture) can mimic Neptune-sized transits and are costly in follow-up time. They can best be identified with the centroiding technique: if the photometric flux is lost off-centre during an eclipse, the flux centroid shifts towards the centre of the target star. Although this method has successfully been employed by the Kepler mission, it has previously not been proven feasible from the ground. We present a new algorithm developed for NGTS that allows detecting centroid shifts with a precision of up to 1/1000th of a pixel. This makes NGTS the first ground-based transit survey ever to successfully implement this technique for candidate auto-vetting.

Identifying and Analysing Protostellar Disc Fragments in Smoothed Particle Hydrodynamics Simulations

Cassandra Hall (University of Leicester)

We present a new method of identifying protostellar disc fragments in a simulation based on density derivatives, and analyse our data using this and the existing CLUMPFIND method, which is based on an ordered search over all particles in gravitational potential energy. Using smoothed particle hydrodynamics, we carry out 9 simulations of a 0.25 M disc around a 1 M star, all of which fragment to form at least 2 bound objects. We find that when using all particles ordered in gravitational potential space, only fragments that survive the duration of the simulation are detected. When we use the density derivative method, all fragments are detected, so the two methods are complementary, as using the two methods together allows us to identify all fragments, and to then determine those that are likely to be destroyed. We find the fragment destruction rate to be around half that predicted from population synthesis models. This is due to fragment-fragment interactions in the early gas phase of the disc, which can cause scattering and eccentricity pumping on short timescales, and affects the fragment's internal structure. We therefore caution that measurements of eccentricity as a function of semi-major axis may not necessarily constrain the formation mechanism of giant planets and brown dwarfs.

The role of gap edge instabilities in setting the depth of gaps in protoplanetary discs

Paul Hallam (Queen Mary University of London)

It is known that an embedded massive planet will open a gap in a protoplanetary disc via angular momentum exchange with the disc material. The resulting surface density profile of the disc is investigated for one dimensional and two dimensional disc models and, in agreement with previous work, it is found that one dimensional gaps are significantly deeper than their two dimensional counterparts for the same initial conditions. We find, via application of one dimensional torque density distributions to planet devoid two dimensional discs, that the excitement of the Rossby wave instability and the formation of Rossby vortices play a critical role in setting the equilibrium depth of the gap. Being a two dimensional instability, this is absent from one dimensional simulations and does not limit the equilibrium gap depth there. We find similar gap depths between two dimensional gaps formed by torque density distributions, in which the Rossby wave instability is present, and two dimensional planet gaps, in which no Rossby wave instability is present. This can be understood if the planet gap is maintained at marginal stability, even when there is no obvious Rossby wave instability present. Further investigation shows the final equilibrium gap depth is very sensitive to the form of the applied torque density distribution, and using improved one dimensional approximations from three dimensional simulations can go even further to reducing the discrepancy between one and two dimensional models, especially for lower mass planets. This behaviour is found to be consistent across discs with varying parameters.

Spontaneous breaking of mean-motion resonances during Type I planet migration

Thomas Hands (University of Zürich)

We present two-dimensional hydrodynamical simulations of pairs of planets migrating simultaneously in the type I regime in a protoplanetary disc. We show that while convergent migration naturally leads to the trapping of these planets in mean-motion resonances, the eccentricity excited by the resonant interaction can alter the planet-disc interactions in a way that leads to the breakdown of these resonances. This mechanism can help to explain the observed paucity of resonances in Kepler multi-transiting systems relative to less-detailed migration models. The effect is more pronounced in highly viscous discs, though persists even in inviscid discs.

Polluted White Dwarfs: Insights regarding the chemistry of terrestrial exo-planets

John Harrison (University of Cambridge)

Current knowledge on the interiors of terrestrial exoplanets is limited. Our best estimates for the interior composition come from observations of the planet's mass and radius, but can lead to degenerate solutions. The frequency of solar system like chemistry and geology in the galaxy is poorly understood. The pollution of white dwarfs by rocky exo-planetary material provides a unique opportunity to study the chemistry and geology of exo-planetary systems. Planetary bodies are scattered inwards from a planetary system that has survived the host star's evolution to the white dwarf phase and accreted by the white dwarfs. Spectra of these polluted white dwarfs yield ratios of key rock forming species, such as Mg/Si, Fe/Si and Ca/Si, as well as ratios of key volatile species, such as C/O. In this study we use data from various heavily polluted white dwarfs to estimate the chemical composition of extrasolar planetesimals, with an aim to constraining the interior compositions of terrestrial planets. We present a model that constrains where in a proto-planetary disc the observed pollutants could have formed. This model takes into account potential variations in the host star chemistry. We use an equilibrium chemistry model, alongside a viscous model for the evolution of a proto-planetary disc, to determine where in the disc the observed compositions could have condensed out of the nebula gas. These results will further our understanding of not only the bulk chemistry of terrestrial planets and the rarity of the solar system's chemistry, but the role host stars play in dictating the chemistry of a terrestrial planet and the role of dynamics in post main sequence systems.

Overcoming stellar activity noise in radial-velocity exoplanet surveys

Raphaëlle Haywood (Harvard-Smithsonian Center for Astrophysics)

The TESS mission will soon discover hundreds of small planets. Many will be ideal candidates to determine their compositions, characterise their atmospheres and assess their habitability. However, these opportunities will not be realised unless we can determine the planets' most fundamental parameter: mass. This is precluded by the magnetic activity of the host stars, which induces important variations in stellar radial-velocity observations. I will present my recent determination of the mass of super-Earth Kepler-21b, in which I account for the star's high levels of magnetic activity using Gaussian process regression. I will also report on my ongoing investigation of the Sun seen as a star by the exoplanet-hunting spectrograph HARPS-N. Since we can resolve the Sun's surface directly and at high resolution, it is the perfect test case to explore the physical origin of activity-driven radial-velocity variations and develop physically-motivated models.

The Centre for Exoplanet Science at the University of St Andrews

Christiane Helling, Andrew C Cameron, Katherine Hawley, Sami Mikhail, Peter Woitke et al. (University of St Andrews)

November 2016: More than 3300 planets are known to orbit stars far beyond the solar system, in planetary systems very different to our own. There may well be hundreds of billions of extrasolar planets in the Milky Way alone. These planets include planetary types not found among the eight planets that orbit our Sun, including mini-Neptunes, super-Earths, rogue or nomad planets and hot gas-giant planets. Are we therefore alone in the Universe? To answer this pertinent question, we seek to understand the formation and evolution of our own solar system and the reasons for this rich planetary diversity.

The Centre for Exoplanet Science (http://www.st-andrews.ac.uk/exoplanets) brings together researchers from different disciplines to find out how planets form in different galactic environments, how their atmospheres evolve, and the relation between the evolutionary history of planets and the emergence of life. We are further interested in the moral, ethical and technical aspects of detecting existent or extinct extra-terrestrial life in distant exosystems, or within our own solar system, and the significance of such a discovery for our societies.

Variable stars with the Next Generation Transit Survey

Vedad Hodzic (University of Cambridge)

The Next Generation Transit Survey is an ongoing exoplanet transit survey experiment seeking to find Neptune and super-Earth sized planets around bright stars suitable for follow-up radial velocity characterisation. NGTS operates 12 independent telescopes and is targeting a new field every 3-4 months at sub-mmag photometric precision. The large volume of photometric data with long time coverage also allows us to study new populations of variable stars. I will present a new framework being developed for the identification and classification of NGTS variable stars.

Ground-based z' band secondary eclipse observations of WASP-103b

Matthew Hooton (Queen's University Belfast)

The z' band offers a particularly useful window in which to study highly irradiated planetary atmospheres. If significant absorption is detected at these wavelengths, it can be a indication that TiO and VO are present in appreciable quantities in the upper atmosphere, which in turn could allude to a low C/O ratio. Here, I present the results of ground-based z' band secondary eclipse observations of WASP-103b, a very highly irradiated planet expected to be significantly distorted by tides.

Accretion of Pebbles onto Gas Giant Planets at Wide Separations

Robert Humphries (University of Leicester)

Numerical SPH simulations are used to study the accretion of ~ 1 mm to ~ 10 cm sized grains (pebbles) and gas onto gas giant planets migrating inwards through their parent discs from separations ~ 100 AU. We explore the parameter space by varying the disc cooling rate, initial planet mass, and pebble size. Whilst gas accretion onto the planet depends strongly on the gas cooling rate inside the planet Hill sphere, the rate of pebble accretion is found to be largely insensitive to this. We show that more massive planets are able to open deeper gaps in the pebble distribution. This limits their subsequent rate of pebble accretion and predicts the inverse correlation between planet mass and metallicity found in exoplanet observations.

Chemical uncertainties in modelling hot Jupiters atmospheres: review and consequences

Eric Hébrard (University of Exeter)

Chemical kinetics models have been widely used in the literature to investigate the chemical compositions of hot Jupiter atmospheres which are expected to be driven away from chemical equilibrium via processes such as vertical mixing and photochemistry. 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. We have used a one-dimensional radiative-convective equilibrium model, ATMO, which has recently been adapted to calculate P-T profiles which are fully consistent with non-equilibrium chemical abundances, including vertical mixing and photochemistry (Drummond et al., 2016). 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 that affect significantly the simulated results (chemical abundances, P-T profile, emission spectra, ...). 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.

The chemical composition of protoplanets formed via gravitational instability

John Ilee (Institute of Astronomy, Cambridge)

There are two competing modes of formation for giant planets and sub-stellar companions – core accretion and gravitational instability (GI). Each process involves drastically different physical mechanisms and raw ingredients, which suggests that the resulting compositions of objects formed by either of this processes may differ significantly. Recent high resolution ALMA observations have, for the first time, detected a system thought to be formed due to gravitational instability. It is therefore essential to constrain the evolution and composition of such objects if we are to fully understand these systems. In this talk, I will introduce new results on time-dependent non-equilibrium chemical modelling of the formation of protoplanetary fragments formed via gravitational instability. Using a 3-dimensional radiation-hydrodynamics code, we have followed the chemical evolution of a protostellar system from birth to the stages of GI-induced planet formation. We find that we are able to resolve the circumplanetary accretion discs and their chemical evolution, of which key species such as H2CO, HCN and CN play an important role in the gas phase. Additionally, we are able to determine the bulk chemical composition of the resulting fragments directly, providing crucial initial conditions for subsequent atmospheric modelling of objects formed via disc instability.

Observing with CHEOPS

Kate Isaak (European Space Agency (ESA))

CHEOPS (CHaracterising ExOPlanet Satellite) is the first exoplanet mission dedicated to the search for transits of exoplanets by means of ultrahigh precision photometry of bright stars already known to host planets, with launch readiness foreseen by the end of 2018. It is also the first S-class mission in ESA's Cosmic Vision 2015-2025. The mission is a partnership between Switzerland and ESA's science programme, with important contributions from 10 other member states. It will provide the unique capability of determining accurate radii for a subset of those planets in the super-Earth to Neptune mass range, for which the mass has already been estimated from ground- based spectroscopic surveys. It will also provide precision radii for new planets discovered by the next generation of ground-based transits surveys (Neptune-size and smaller). By unveiling transiting exoplanets with high potential for in-depth characterization, CHEOPS will also provide prime targets for future instruments suited to the spectroscopic characterisation of exoplanetary atmospheres.

The high photometric precision of CHEOPS will be achieved using a photometer covering the $0.35 - 1.1\mu$m waveband, designed around a single frame-transfer CCD which is mounted in the focal plane of a 30 cm equivalent aperture diameter, f/5 on-axis Ritchey-Chretien telescope. 20% of the observing time in the 3.5 year nominal mission will be available to Guest Observers from the Community. Proposals will be requested through open calls from ESA that are foreseen to be every year, with the first 6 months before launch.

In this poster I will provide an overview of how to obtain data from CHEOPS, with a particular focus on the CHEOPS Guest Observers Programme.

Cross matching with the Next Generation Transit Survey

James Jackman (University of Warwick)

I will present an overview of a recent algorithm developed to perform cross matching of existing astronomical catalogues, in particular Gaia and 2MASS, with the Next Generation Transit Survey (NGTS). This algorithm can be used to aid identification of potential M Dwarfs, along with more general host star characterisation.

Ultrastable radial velocity spectrograph

Hugh Jones (University of Hertfordshire)

Report on work at the University of Hertfordshire to produce an ultrastable radial velocity spectrograph

Multi-epoch observations of the HD 189733 system with XMM-Newton

George King (University of Warwick)

As the home to one of the two prototypical transiting hot Jupiters, HD 189733 is one of the most studied exoplanetary systems to date. Its brightness and relatively close distance in the solar neighbourhood have allowed detailed analyses at wavelengths spanning many orders of magnitude on the electromagnetic spectrum. Studies of the system at high energies have revealed an active corona, with numerous X-ray flares identified. Possible star-planet interactions in the system have also been explored. We are currently using data from XMM-Newton to investigate further some of the exciting, but as yet tentative findings at X-ray wavelengths over the past few years. We will present the latest findings in our ongoing analysis of the high energy output of the host star, and the resulting implications for the close in planet.

Ground-based transmission spectroscopy of hot Jupiters using WHT/ACAM

James Kirk (University of Warwick)

Transmission spectroscopy is revealing a huge diversity of hot Jupiter atmospheres. In order to improve our understanding of the underlying processes we must increase the sample of studied planets, making ground-based observations a necessity. While there has been success in the detection of narrow absorption features in the atmospheres of hot Jupiters from the ground, detections of features extending across the optical spectrum have been harder to come by. I will present the recent detection of a Rayleigh scattering slope in the atmosphere of the hot Jupiter HAT-P-18b, only the third such detection from the ground, which highlights the role that ground-based observations have to play. I will also discuss how this discovery fits in to our larger programme of hot Jupiter characterisation from the ground.

Constraining helium abundances with precise binary parameters.

Jessica Kirkby-Kent (Keele University)

Stellar evolutionary models are important for determining the mass and age of planet host stars. Along with issues in models under-predicting radii and over-predicting temperatures for low-mass stars, there is also a growing need for the parameters such as the helium abundance, convective overshooting and mixing length to be properly calibrated, in order to provide the best possible estimates for the age of these planetary systems. The core-overshooting parameter can be found through asteroseismology, but there is a degeneracy between mass and helium abundance and finding appropriate pulsations is not possible for all types of stars. Detached eclipsing binaries (EBs) containing a subgiant component, with precisely measured masses and radii provide a great opportunity to constrain parameters such as helium abundance. We have shown this for systems such as AI Phe and LL Aqr. With masses and radii measured to better than 1%, a new binary, J0639, looks to be a good candidate to test the models and help calibrate the free parameters.

Ca II H & K absorption variation around WASP-12

Kristine Lam (University of Warwick)

Ca II H & K line profiles are stellar activity indicators. Studies showed that some stars, particularly planet hosting stars, have low log(R'hk) stellar activity indices. One such example is WASP-12, which has shown to have no emission in the Ca II H & K line cores. WASP-12b has a very short period of approximately 1-day and the planet is heavily inflated by its host star. It is thought that the material of the planet is stripped off as a result of its proximity to the parent star. The material loss covers the entire system and absorbs extra emission from the star along the line-of-sight, leading to the complete absorption in the line profiles. In this work, we study the observed Ca II H & K line profiles of WASP-12 and investigate the orbital variation of the system.

High energy exoplanet transits

Joe Llama (Lowell Observatory)

High energy (X-ray / UV) observations of transiting exoplanets have revealed the pres- ence of extended atmospheres around a number of systems. At these energies, stellar radiation is absorbed in the upper atmosphere of the planet, making X-ray / UV tran- sits an exciting tool for investigating the composition of exoplanetary atmospheres. However, the effects of stellar activity on transits at these wavelengths is far from un- derstood. In X-rays 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. This makes measuring the true planet-to-star radius ratio challenging. The Sun offers a unique opportunity to study the impact of stellar activity on high energy transits. Using disk resolved soft X-ray and UV images from NASA's Solar Dynamics Observatory taken over the last solar cycle I will show how both occulted and unocculted active regions can mimic an inflated planetary atmosphere by changing the depth and shape of a transit profile. I will also show how the disk integrated Lyman-α Solar irradiance varies on both short and long timescales and how this variability can also impact our ability to recover the true radius ratio of a transiting exoplanet. Finally, I will present techniques to overcome these challenges in high-energy transits.

The irradiated atmopsheres of brown dwarfs

Emma Longstaff (University of Leicester)

Brown dwarfs offer a unique insight into the complex and fascinating topic of exo-atmospheres. They are not massive enough to burn hydrogen during their lifetime; thus brown dwarfs have cooler atmospheres that are more akin to planets than stars. To make a comparison, brown dwarfs and exoplanets must be observed in similar environments i.e. close in to their host star. Due to the brown dwarf desert, brown dwarfs are rarely found around main sequence stars and separating the spectra of these two bodies is no simple task. Brown dwarfs around white dwarfs, whilst even rarer, provide a unique opportunity to observe an irradiated sub-stellar atmosphere with little interference from the primary star. In these systems the brown dwarf is irradiated in a similar way to a hot Jupiter however, brown dwarfs have an advantage as they are brighter and their atmospheric models are more advanced than their exoplanet counterparts. I will talk about the two shortest period white dwarf + brown dwarf post common envelope binaries. These two systems are similar in terms of masses and separation, despite this they are behaving distinctly differently. I will report on the most recent analysis of these objects including new Xshooter and Swift data.

Peering Through The Clouds: Retrieving Properties of Transiting Exoplanet Atmospheres

Ryan MacDonald (University of Cambridge)

Interpretations of transmission spectra have been undermined by apparent obscuration due to clouds/hazes. It is debated whether weak H2O features seen in numerous hot Jupiter spectra are due to clouds or inherently depleted oxygen. In particular, assertions of solar H2O abundances have relied on making a priori model assumptions, e.g. chemical/radiative equilibrium. To address this problem I will introduce POSEIDON, a two-dimensional atmospheric retrieval algorithm including generalised inhomogeneous clouds, that is able to simultaneously retrieve precise chemical abundances and cloud properties from cloudy transiting exoplanets. I will present the first application of POSEIDON to a transmission spectrum, that of the hot Jupiter HD 209458b, offering new insights into its atmosphere at the day-night terminator. Amongst our results, I will discuss: the first detection of Nitrogen chemistry (NH3 and/or HCN) in an exoplanet atmosphere, non-uniform cloud coverage, high-altitude hazes, and robustly sub-solar H2O. NH3 is identified as the probable cause of the nitrogen chemistry, with its abundance strongly suggestive of disequilibrium chemistry. These results offer a new opportunity to retrieve cloudy atmospheres using high-precision HST and JWST spectra.

HD 209458b in New Light: Detection of Nitrogen Chemistry, Patchy Clouds and Sub-Solar Water

Ryan MacDonald (University of Cambridge)

Interpretations of transmission spectra have been undermined by apparent obscuration due to clouds/hazes. It is debated whether weak H2O features seen in numerous hot Jupiter spectra are due to clouds or inherently depleted oxygen. In particular, assertions of solar H2O abundances have relied on making a priori model assumptions, e.g. chemical/radiative equilibrium. To address this problem I will introduce POSEIDON, a two-dimensional atmospheric retrieval algorithm including generalised inhomogeneous clouds, that is able to simultaneously retrieve precise chemical abundances and cloud properties from cloudy transiting exoplanets. I will present the first application of POSEIDON to a transmission spectrum, that of the hot Jupiter HD 209458b, offering new insights into its atmosphere at the day-night terminator. Amongst our results, I will discuss: the first detection of Nitrogen chemistry (NH3 and/or HCN) in an exoplanet atmosphere, non-uniform cloud coverage, high-altitude hazes, and robustly sub-solar H2O. NH3 is identified as the probable cause of the nitrogen chemistry, with its abundance strongly suggestive of disequilibrium chemistry. These results offer a new opportunity to retrieve cloudy atmospheres using high-precision HST and JWST spectra.

Direct Imaging of Wide Separation Planets and Scattered Light Debris Disks

Elisabeth Matthews (University of Exeter)

We are performing a search for low-mass companions around young, highly dusty stars using the SPHERE instrument on the VLT. It has been suggested that these dusty systems, which can be identified by the excess infrared emission of the target, may indicate the presence of planets. In our survey, we have focused specifically on targets where there is not only evidence of dust, but evidence that the dust has been carved into multiple, distinct, debris belts. The resulting implication is that there may be one or more giant planets carving the gaps into these debris belts, and therefore the shape and size of the belts can reveal additional information about potential planets in the system that are too small to directly image. In this poster I will present our survey for low-mass companions, which has already revealed scattered light images of three debris disks, and several promising candidate companions.

Understanding the morphology of the protoplanetary disc, Elias 2-27

Farzana Meru (University of Cambridge)

Recent observations of protoplanetary discs are starting to hint that the young turbulent self-gravitating disc phase is more important for planet formation than previously thought. In contrast to the standard paradigm for planet formation, these results may now have pushed the likely era of planet formation into the brief, early self-gravitating stage of disc evolution. One such example is the Elias 2-27 protoplanetary disc which exhibits strong spiral structures out to approximately 250au. Through the results of recent numerical simulations I will discuss whether Elias 2-27 could be the first observation of a self-gravitating disc.

Blind extraction of exoplanetary spectra

Giuseppe Morello (University College London)

In the last decade, remote sensing spectroscopy enabled characterization of the atmospheres of extrasolar planets. Transmission and emission spectra of tens of transiting exoplanets have been measured with multiple instruments aboard Spitzer and Hubble Space Telescopes as well as ground-based facilities, revealing the presence of chemical species in their atmospheres, and constraining their temperature and pressure profiles. Early analyses were somehow heuristic, leading to some controversies in the literature.A photometric precision of 0.01% is necessary to detect the atmospheric spectral modulations. Current observatories, except Kepler, were not designed to achieve this precision. Data reduction is necessary to minimize the effect of instrument systematics in order to achieve the target precision. In the past, parametric models have extensively been used by most teams to remove correlated noise with the aid of auxiliary information of the instrument, the so-called optical state vectors (OSVs). Such OSVs can include inter- and intra-pixel position of the star or its spectrum, instrument temperatures and inclinations, and/or other parameters. In some cases, different parameterizations led to discrepant results. We recommend the use of blind non-parametric data detrending techniques to overcome those issues. In particular, we adopt Independent Component Analysis (ICA), i.e. a powerful blind source separation (BSS) technique to disentangle the multiple instrument systematics and astrophysical signals in transit/eclipse light curves. ICA does not require a model for the systematics, thence it can be applied to any instrument with little changes, if any. ICA-based algorithms have been applied to Spitzer/IRAC and synthetic observations in photometry (Morello et al. 2014, 2015, 2016; Morello 2015) and to Hubble/WFC3, Hubble/NICMOS and Spitzer/IRS and Hubble/WFC3 in spectroscopy (Damiano, Morello et al., in prep., Waldmann 2012, 2014, Waldmann et al. 2013) with excellent results. In this conference, I will illustrate the detrending algorithms optimized to specific instruments and the results obtained over new observations (Damiano et al., under review).

Stacking periodograms: tracking the significance of a periodic signal

Annelies Mortier (University of St Andrews)

Distinguishing between a signal induced by stellar activity or a planet is the main challenge in radial velocity searches for low-mass exoplanets these days. Even when the presence of a transiting planet and hence its period are known, stellar activity can be the main barrier in nailing down the correct amplitude of the radial velocity signal. Several tools are being used to help understand which signals come from stellar activity in the data. We present a new tool, using the Bayesian general Lomb-Scargle periodogram, that can be used for the purpose of identifying periodicities caused by stellar activity, based on the principle that stellar activity signals are variable and incoherent. This tool can also be used to track the SNR of the detection over time.

Stellar wind-planet interactions: computing auroral radio emissions and observational testing of the Radiometric Bode's Law

Jonathan Nichols (University of Leicester)

We present calculations of the auroral radio powers expected from exoplanets with magnetospheres driven by an Earth-like magnetospheric interaction with the solar wind. Specifically, we compute the twin cell-vortical ionospheric flows, currents, and resulting radio powers resulting from a Dungey cycle process driven by dayside and nightside magnetic reconnection, as a function of planetary orbital distance and magnetic field strength. We include saturation of the magnetospheric convection, as observed at the terrestrial magnetosphere. We show that the radio power increases with magnetic field strength for magnetospheres with saturated convection potential, and broadly decreases with increasing orbital distance. We show that the magnetospheric convection at hot Jupiters will be saturated, and thus unable to dissipate the full available incident Poynting flux, such that the magnetic Radiometric Bode's Law (RBL) presents a substantial overestimation of the radio powers for hot Jupiters. Our radio powers for hot Jupiters are $\sim$5-1300 TW for hot Jupiters with field strengths of 0.1-10 BJ orbiting a Sun-like star, on the limit of detectability using LOFAR for a distance of 15 pc. We further present calculations of the total auroral power output as a function of solar wind kinetic energy and Poynting flux as observed at Earth over many years, and compare with expectations based on the RBL.

Radial Velocity Eclipse Mapping of Exoplanets

Nikolay Nikolov (University of Exeter)

We investigate the theoretical and observational perspective of the Rossiter-McLaughlin effect during secondary eclipse (RMse) ingress and egress for transiting exoplanets. Near secondary eclipse, when the planet passes behind the parent star, the star sequentially obscures light from the approaching and receding parts of the rotating planetary surface. The temporal block of light emerging from the approaching (blue-shifted) or receding (red-shifted) parts of the planet causes a temporal distortion in the planet's spectral line profiles resulting in an anomaly in the planet's radial velocity curve (Figure 1). We demonstrate that the shape and the ratio of the ingress-to-egress radial velocity amplitudes depends on the planetary rotational rate, axial tilt and impact factor (i.e. sky-projected planet spin-orbital alignment). In addition, line asymmetries originating from different layers in the atmosphere of the planet could provide information regarding zonal atmospheric winds and constraints on the hot spot shape for giant irradiated exoplanets. The effect is expected to be most-pronounced at near-infrared wavelengths, where the planet-to-star contrasts are large. We create synthetic near-infrared, high-dispersion spectroscopic data and demonstrate how the sky-projected spin axis orientation and equatorial velocity of the planet can be estimated. We conclude that the RMse effect could be a powerful method to measure exoplanet spins.

3D modelling of facular spectral contrasts.

Charlotte Norris (Imperial College London)

Modelling the spectral contrasts of faculae for different limb angles and stellar spectral types will improve the modelling of stellar photospheric variability and, therefore, the accuracy of the properties of planets obtained using exoplanet transit spectroscopy. These calculations are done by using a radiative transfer algorithm (ATLAS9) on magneto convection simulations at multiple angles. We have derived facular contrasts for solar twins. I will present these as a function of wavelength and limb angle and discuss the expected differences for early K stars.

Machine learning with the WASP archive to detect long-duration deep eclipses

Hugh Osborn (University of Warwick)

Deep, long-duration eclipses have been found around a variety of stellar types and from a range of mechanisms. They include dust disc interaction (UX Ors RW Aur), circumsecondary (EE Cep, KH-15D) and circumplanetary (J1407) material in eclipse, circumstellar discs around giant star companions (TYC-2505-672-1) and as-yet unexplained dimmings around main sequence stars (KIC8462852). To detect more search events, a targeted search of deep eclipses was performed on photometry of every bright (¡13.5 mag) star observed by WASP from 2004 to 2014. Injections of regular, deep eclipses with durations from 5 to 50 days were also performed to test the recovery process. We trained a supervised machine learning code on these injected detections, detecting around 40% of all injected eclipses with a false positive rate of only 7%. A dozen detected eclipses, for which follow-up is ongoing, are shown here. This technique also allows us to estimate an occurrence rate of such events around all stars.

Developing a grid of cool brown dwarf atmospheres

Mark Phillips (University of Exeter)

Many forward models of brown dwarf atmospheres include the opacity of a variety of clouds to suppress the flux in the near-infrared and reproduce spectral observations. However, it has recently been suggested by Tremblin et al 2016 that a thermo-chemical instability induced by nitrogen or carbon non-equilibrium chemistry can reduce the temperature gradient in the atmosphere, lowering the near-infrared flux and reproducing spectral observations without the need to invoke cloud opacity. I will present results from the development of a cloud-free grid of model brown dwarf atmospheres between Teff=200-1800K and log(g)=2.0-5.5, generated using our 1D radiative-convective equilibrium code ATMO within which the adiabatic index is modified to reduce the temperature gradient and match observations. The effects of dis-equilibrium chemistry due to vertical mixing and the condensation of NH3 and H2O are included to produce spectra of the coolest Y dwarfs, which are of particular interest as ever-improving instrumentation becomes more sensitive to these cool objects.

Observable Signatures of Clouds in Exoplanetary Transit Spectra

Arazi Pinhas (Institute of Astronomy, Cambridge)

Transmission spectra of exoplanetary atmospheres have been used to infer the presence of clouds/hazes. Such inferences are typically based on spectral slopes in the optical deviant from gaseous Rayleigh scattering or low-amplitude spectral features in the infrared. We investigate three observable metrics that could allow constraints on cloud properties from transmission spectra, namely, the optical slope, the uniformity of this slope, and features in the infrared. We derive these metrics based on model transmission spectra for a wide range of condensate species, particle sizes, and scale heights. Firstly, we investigate possible degeneracies between the various cloud properties for an observed slope. We find, for example, that spectra with very steep optical slopes suggest sulphide clouds (e.g. MnS, ZnS, Na_2S) in the atmospheres. Additionally, observable signatures of homogeneous clouds require condensate scale heights greater than $\sim 0.4\times$ the atmospheric scale height, with inhomogeneous clouds a possibility for lower values. Secondly, (non)uniformities in optical slopes provide additional constraints on cloud properties, e.g., MnS, ZnS, TiO_2, and Fe_2O_3 have significantly non-uniform slopes. Thirdly, infrared spectra provide an additional powerful probe into cloud properties, with SiO_2, Fe_2O_3, Mg_2SiO_4, and $MgSiO_3$ bearing strong features observable with JWST. We investigate currently observed spectra of several known hot Jupiters and discuss their implications. In particular, no single or composite condensate species considered here conforms to the steep and non-uniform optical slope of HD 189733b. Our work highlights the importance of the three above metrics to investigate cloud properties in exoplanetary atmospheres using high-precision transmission spectra and detailed cloud models.

Measuring the Effective Pixel Positions of the HARPS3 CCD

Hall Richard (University of Cambridge)

Current radial velocity (RV) spectrographs have a measurement precision of around 1m/s. The next generation of radial velocity spectrographs will need a measurement precision of 0.1m/s in order to confirm the presence of Earth-mass planets orbiting Sun-like stars. Part of this increase in precision will come from the measurement of the pixel positions of the detector. These measurements will improve the precision of the wavelength solution used to calculate the presence of planets. In this poster I present the experiment we have built to measure these pixel positions along with the data analysis techniques used to create a pixel displacement map of the CCD.

Infrared Variability in Dusty White Dwarfs

Laura Rogers (University of Cambridge)

Collaborators: Amy Bonsor and Siyi Xu. Evidence for the survival of outer planetary systems to the white dwarf phase comes from observations of planetary material polluting the atmospheres of white dwarfs. These observations are unique in providing the composition of exo-planetary material. Infrared observations of dust very close to white dwarfs reveal how planetary material arrives in the atmospheres of white dwarfs. We expect the scattering of planetary bodies that leads to pollution to be a stochastic process, with the potential for variability on human timescales. Such variability has been found for the white dwarf WD J0959-0200, where a drop in K band flux of 20% was observed within one year. We present the results from further monitoring campaigns of dusty white dwarfs using UKIRT (WFCAM) in the J, H and K bands from 2014 to 2016.

UV to IR Transits of Earth-like planets around FGKM stars

Sarah Rugheimer (University of St. Andrews)

Transmission spectroscopy has been the key method to characterize exoplanets to date. With JWST we will be obtaining the first observations of potentially Earth-like, terrestrial exoplanet atmospheres. We present our calculations for transmission spectroscopy for Earth-like planets orbiting FGKM stars from 0.1 to 20 microns, probing the UV to IR range and present our findings with relevance to JWST as well as the proposed future UV mission, LUVIOR.

Hunting for Planets in a Random Forest

Nicole Schanche (University of St Andrews)

Since the onset of the Wide Angle Search for Planets (WASP) program, more than 160 transiting exoplanets have been identified. However, there remains a large number of light curves yet to be analyzed. In order to increase the efficiency of the planet search, a more automated process is needed to comb through the light curves and identify potential transits. To this end, we create a training and test dataset made up of stellar light curves previously identified by WASP team members as having a genuine transit (either from a planet or an eclipsing binary) or a non-transit. Using the training data, we build a random forest to distinguish between the two groups. The forest obtains an accuracy of $\sim 94\%$ when applied to the testing dataset. The random forest is then applied to previously unclassified data to find new transit candidates.

The Panchromatic Comparative Exoplanet Treasury Program

David Sing (University of Exeter)

HST has played the definitive role in the characterization of exoplanets and from the first planets available, we have learned that their atmospheres are incredibly diverse. The Panchromatic Exoplanet Treasury Programme (PanCET) will be the first large-scale, simultaneous UVOIR comparative study of exoplanets. With full wavelength coverage, an entire planet's atmosphere can be probed simultaneously and with sufficient numbers of planets, we can statistically compare their features with physical parameters for the first time. This panchromatic programme will build a lasting HST legacy, providing the UV and blue-optical spectra unavailable to JWST. From these observations, chemistry over a wide range of physical environments will be probed, from the hottest condensates to much cooler planets where photochemical hazes could be present. I will present the early results and the current status of the programme.

Current status of the TEPCat catalogue of transiting extrasolar planets

John Southworth (Keele University)

Since 2011 the TEPCat catalogue has been freely available at http://www.astro.keele.ac.uk/jkt/tepcat/. It is a continuously-updated critical compilation of the physical properties of all known transiting extrasolar planetary systems, available in multiple formats. TEPCat lists mass, radius gravity, density and temperature measurements for each star and planet plus orbital period, eccentricity, semimajor axis and obliquity (where available). I present the current status of the catalogue plus an overview of the properties of the known transiting extrasolar planets and their host stars.

Dust cloud evolution in substellar atmospheres via plasma deposition and plasma sputtering

Craig Stark (Abertay University)

In contemporary substellar model atmospheres, dust growth occurs through neutral gas-phase surface chemistry driven by stochastic kinetic gas dynamics. Recently, there has been a growing body of theoretical and observational evidence suggesting that ionization processes can also occur. As a result, atmospheres are populated by regions composed of plasma, gas and dust, and the consequent influence of plasma processes on dust evolution is enhanced. This paper introduces a new model of dust growth and destruction in substellar atmospheres via plasma deposition and plasma sputtering. Using example data from model substellar atmospheres, we compare plasma deposition and sputtering rates to those from neutral gas-phase surface chemistry and determine the regimes of influence. We calculate the plasma sputtering yield and discuss the circumstances where plasma sputtering dominates over deposition.

High precision spectroscopic analysis of exoplanet transits using differential least-squares deconvolution

John Strachan (Queen Mary University of London)

When a feature appears on the surface of a star, the spectrum observed from Earth experiences tiny changes that are registered in its spectral lines. The features range from spots and magnetically active regions to transiting planets blocking part of the stellar disk. High resolution spectroscopy of transiting exoplanets from systems such as HARPS has enabled details of the exoplanet such as the projected spin-orbit misalignment angle to be estimated from analysis of these tiny changes to the spectral lines. Three main techniques have been used to determine these details and all have shortcomings. The first technique is based on the radial-velocity distortion during a planetary transit (the Rossiter-McLaughlin effect). Systematic errors can occur in this method arising from the time-variable asymmetry of the stellar spectral lines during transit and solutions identified can be degenerate. The second technique uses Least Squares Deconvolution where a template based on a weighted atomic linelist is used. Systematic errors, particularly for late type stars, occur here due

to the atomic linelist being incomplete and due to the non-linearity of line-blends. The third technique is based on the use of the Cross Correlation Function where systematic errors also occur due to line blending and again this becomes very severe for late type stars. In order to circumvent these issues, we have developed a method called differential Least Squares Deconvolution (dLSD). This method uses a high signal to noise template produced by combining several spectra from the star itself and solving for the convolution kernel that minimises the matching of this template to the actual observations. In the case of transiting planets, we show that this Kernel function contains the details of the Doppler shadow of the transiting exoplanet, and we fit to a forward model in order to obtain the projected spin-orbit misalignment angle of the system and rotational velocity of the parent star. We also look at the potential for this method to detect exoplanets using refelected light.

WASP-167b/KELT-13b: Joint Discovery of a Hot Jupiter Planet Orbiting a F1V Star

Lorna Temple (Keele University)

We report the WASP/KELT joint discovery of a new transiting hot Jupiter, dubbed WASP-167b/KELT-13b. The planet has an orbital period of 2.02 days. It transits a V = 10.52, F1V star with [Fe/H] = 0.1 +/- 0.1. WASP-167/KELT-13 is a fast rotating star, with P_rot < 1.75 days, meaning that it is one of few planet hosts which rotate faster than their planet's orbital speed. It is also one of the hottest transiting-planet hosts found to date, with T_eff = 7000 +/- 250 K. This puts it in a largely unexplored region of parameter space. We use radial velocities to show that the mass of the transiting object is within planet mass range and use Doppler tomography to confirm its planetary nature. The planet has a projected spin-orbit misalignment angle of -169 +/- 1 degrees. It orbits in the retrograde direction, making it the 6th known retrograde transiting planet with a hot host star (T_eff > 6250K). We also find evidence of non-radial stellar pulsations in the host star. The star's spectral class puts it within the typical range of Gamma-Doradus variables, but lack of out-of-transit photometric follow-up means that an analysis of the pulsation modes is beyond the scope of this work. This work demonstrates the power of Doppler tomography as a means of confirmation of planetary status for candidates with hot, fast-rotating host stars. It also shows the advantages of collaboration between planet surveys, which here has allowed a robust characterization of the transit lightcurve.

Orbital evolution during planet-disc interactions

Jean Teyssandier (University of Cambridge)

The origin and wide distribution of eccentricities in planetary systems remains to be explained, in particular in the context of planet-disc interactions. In this talk I will present a study of the evolution of eccentricity in discs and planets. I will compare the predictions of a linear secular theory against direct hydrodynamical simulations. Both the theory and simulations argue in favour of eccentricity growth for giant planets. I will discuss what these results imply for the orbital structure of protoplanetary discs and young planetary systems.

The changing face of α Centauri B: probing plage and stellar activity in K dwarfs

Andrew Thompson (Queen's University Belfast)

Detailed knowledge of stellar activity is crucial for understanding stellar dynamos, as well as pushing exoplanet radial-velocity detection limits towards Earth analogue confirmation. We directly compare archival High Accuracy Radial velocity Planet Searcher spectra taken at the minimum in α Cen B's activity cycle to a high-activity state when clear rotational modulation of log R HK is visible. Relative to the inactive spectra, we find a large number of narrow pseudo-emission features in the active spectra with strengths that are rotationally modulated. These features most likely originate from plage, spots or a combination of both. They also display radial velocity variations of $\sim$ 300 m s^{-1} - consistent with an active region rotating across the stellar surface. Furthermore, we see evidence that some of the lines originating from the ?active immaculate' photosphere appear broader relative to the ?inactive immaculate' case. This may be due to enhanced contributions of, for example, magnetic bright points to these lines, which then causes additional line broadening. More detailed analysis may enable measurements of plage and spot coverage using single spectra in the future.

The TRAPPIST-1 system

Amaury Triaud (University of Cambridge)

This poster will accompany the talk, displaying publicly the data we collected on the system. We have a 22 day continuous photometric monitoring, a triple transit, a mass/radius diagram, and a radius/irradiation diagram.

New tools for simulating and analysing HST / WFC3 spatial scans

Angelos Tsiaras (University College London)

Currently, the WFC3 camera on-board the Hubble Space Telescope is the most powerful instrument to perform infrared transit spectroscopy of exoplanets. In particular, it is the use of the spatial scanning technique that has improved the achievable precision of the observations. However, due to geometric distortions, the structure of the spectra produced by WFC3 is field-dependent. To take into account this behaviour, we have introduced a new approach in characterising spatially scanned spectra where the final spectrum is described as the superposition of many different starring spectra. Based on this method we have developed two new software tools in order to simulate and analyse HST/WFC3 spatially scanned spectra. We plan to make the tools presented here available to the community in the near future. In terms of data analysis, our approach ensures a more consistent treatment between slow and fast spatial scans and gives us the opportunity to analyse even longer spatially scanned spectra. On the other hand, simulated observations with more realistic systematics can be used to test the effectiveness of different data analysis methods in a variety of different scenarios. This approach is critical for method validation and optimising future observing strategies.

Zonal flow evolution in discs

Riccardo Vanon (DAMTP, University of Cambridge)

Zonal flows can play a crucial role in planetesimal growth within protoplanetary discs as their presence can alter the coupling between planetesimals and disc gas, helping the former to overcome their inward migration due to gas drag when reaching the 'metre-sized' barrier, while simultaneously promoting their growth. I will present a linear stability analysis for a compressible, viscous self-gravitating (SG) Keplerian disc with constant cooling and horizontal thermal diffusion, when a freely evolving zonal flow is present. Although the solutions, obtained using the shearing sheet model, are well known for the inviscid problem with no cooling or diffusion, it is non-trivial to predict the effect caused by the introduction of non-ideal effects. The calculation, focusing on perturbations of wavelength $\sim H$ and therefore representing an extension to the classical analysis of thermal and viscous instabilities, allows to study the stability of the potential vorticity (PV) and entropy slow modes. This is used to establish whether zonal flow grow or decay as a result of non-ideal effects such as viscous interactions, cooling and thermal diffusion. The instability, analysed by means of both the eigenvalue problem and the Routh-Hurwitz stability criteria, appears boosted by increasing the values of γ and of the Prandtl number, while it is quenched by fast cooling. The coupling between the slow modes, which is negligible in the classical analysis, is also found to be of importance particularly for Prandtl numbers higher than unity.

J0555-57, A TRAPPIST-I analog eclipsing F7 binary

Alexander v. Boetticher (Cambridge, Cavendish Astrophysics)

M-dwarf stars are the most common stellar objects in our galaxy and are excellent candidates for the detection and atmospheric characterisation of earth-sized exoplanets. This requires an accurate knowledge of the physical properties of the planet's host-stars. We aim to improve our understanding of low-mass M-dwarf stars, by providing a large sample of objects with accurately determined properties. In this context we report the discovery of the single-line low-mass eclipsing binary J0555-57. We use high-precision transit observations and spectroscopic radial velocities in a joint Markov Chain Monte Carlo fit to determine the host-star radius, the companion mass and radius and derived companion properties. J0555-57 consists of a solar-like primary star and an M-type dwarf companion on a weakly eccentric 7.7577 day orbit. We determine a companion mass and radius of $84.2^{2.4}_{2.3}\,\mathrm{M}_{Jup}$ and $0.82^{0.20}_{0.04}\,\mathrm{R}_{Jup}$. This places J0555-57b uniquely just above the hydrogen-burning mass-limit that separates stellar objects and sub-stellar brown dwarfs.

The chemical composition of extrasolar planetesimals

David Wilson (University of Warwick)

Disrupted planetesimals at white dwarfs provide the only avenue to directly measure the bulk composition of extrasolar rocky objects. Over a dozen systems now have high-resolution, wide-coverage spectra providing abundance measurements of a plethora of metals. Here we present Hubble Space Telescope and Very Large Telescope spectroscopy of four additional white dwarfs where the main chemical constituents of the Earth (oxygen, magnesium, silicon and iron) are detected. We place these new results in the context of the debris sample as a whole, and discuss the implications for aspects of planetary chemistry such as carbon content, the occurrence of water, and mantle behaviour.

Radiation Pressure on Dust Grains in Protoplanetary Discs

Peter Woitke (University of St Andrews)

Small dust grains at the tau=1 surface of protoplanetary discs are pushed by radiation pressure forces, radially outward by the photons coming from the star, and vertically upward by the photons emitted from and scattered by the disc. We compute these forces in full radiative transfer disc models (ProDiMo) and study the trajectories of dust particle of various sizes in the co-rotating frame including gravity and friction. In particular the small fluffy dust grains (porous aggregates) can be expected to be lifted upwards, and be lost in form of a tenuous wind on long timescales, which might have an impact on scattered light observations and on disc evolution.

Chemistry in the (Idealised) Unified Model Planet Simulator

Jack Yates (University of Edinburgh)

We use the Met Office Unified Model (UM) to describe the chemical composition of Earth-like exoplanets. We are building on work led by the U. Exeter that has applied the UM to study the atmospheric dynamics of hot Jupiters and tidally-locked planets. To demonstrate the composition capability of the UM we have used a simple online chemistry scheme. We will present initial results from our model, with a focus on implications for the development of a habitable planet, and outline our goals for future simulation.

Spectroscopy of Hot Rocky Super-Earths

Sergey Yurchenko (University College London)

S. Yurchenko, J. Tennyson, B. Mant, L. McKemmish, K. Chubb: Currently, there are about 40 known super-Earths detected, of which less than dozen are transiting planets suitable for atmospheric follow-up observations. These objects usually have very short orbital periods, hence hot atmospheres. Some of them are evaporating and for most water is a major constituent. The massive amounts of water in these atmospheres can melt rocks and put its components into the atmosphere. The vaporizing water, hydrated minerals and carbonate rocks in specific for these objects will necessarily have different spectroscopic signatures than cooler planets, and thus will influence interpretation of the atmospheric observations. At present interpretation is severely impacted by the lack of corresponding spectroscopic data. The massive number of absorbers in the atmosphere also affects the cooling and therefore the evolution of the young hot objects; comprehensive molecular data is crucial to model these processes as well. The molecular opacities specific for interpretation of spectra of hot rocky super-Earths will be discussed. The data for some important absorbers are already available in the Exomol database. This includes water, methane, ammonia, carbon dioxide, and sulfur dioxide. Other important sources of opacities such as NaOH, KOH, SiO2, PO, HCCH are missing. Some diatomics are only partially covered, e.g. the IR line lists exists for CO, SiO, KCl, NaCl, NO, but no NIR, Vis or UV opacity data are available. These data, when constructed, will enable the interpretation of present and future exoplanet spectroscopic data. The quality of our data is also suitable for complementary high-dispersion spectroscopic observations at resolving powers of 100,000 and better.

Molecular line lists for exoplanet and other hot atmospheres

Sergey Yurchenko (University College London)

Jonathan Tennyson, Sergei N. Yurchenko, Ahmed F. Al-Refaie, Emma J. Barton, Katy L. Chubb, Phillip A. Coles, S. Diamantopoulou, Maire N. Gorman, Christian Hill, Lorenzo Lodi, Laura K. McKemmish, Alec Owens, Oleg L. Polyansky, Clara Sousa-Silva, Daniel S. Underwood, Andrey Yachmenev, Emil Zak: Fundamental molecular data play a key role for spectral characterization of astrophysical objects cool enough to form molecules in their atmospheres (cool stars, extrosolar planets and planetary discs) as well as in a broad range of terrestrial applications. However the laboratory data for a number of key species is absent, inaccurate or incomplete. The ExoMol project aims to prove comprehensive line lists for all molecules likely to be observable in exoplanet atmospheres in the foreseeable future. This is a huge undertaking which will mean providing in excess of tens of billions of spectral lines for a large variety of molecular species. The physics of molecular absorptions is complex and varies between different classes of absorbers, which are therefore divided into following topics (a) diatomic, (b) triatomics, (c) tetratomics, (d) methane and (e) larger molecules. Special techniques are being developed to treat each case. The line lists for a number of key atmospheric species currently available from ExoMol (www.exomol.com). We will present examples of molecular spectra computed using the ExoMol line lists and applied for modelling spectroscopy of exoplanets and cool stars.

Generation of an optimal target list for ARIEL

Tiziano Zingales (UCL / INAF)

In the past twenty years space missions and ground-based surveys have discovered over 3000 exoplanets. The characterization of their atmospheres is the necessary next step to understand what are these planets made of, how did these planets form, how do they evolve and other fundamental questions. ARIEL is one of the three candidates for the next ESA medium class mission (M4) expected to be launched in 2026. ARIEL will be dedicated to the study of a large sample of exoplanetary atmospheres through simultaneous combined-light (transit, eclipse, phase-curves etc.) spectroscopy in the 0.5-7.8 micron wavelength range, we are therefore working at the optimization of the list of planetary targets to be observed during the mission life-time. A complete list of targets for 2026 needs to include both a select sample of already known exoplanets and a select sample of exoplanets expected to be discovered in the next decade. Thanks to the Kepler space mission results, we can estimate the occurrence rate of transiting exoplanets around the stars in the solar neighborhood (Fressin et al, 2013). Present and future space missions (K2, GAIA, TESS, Cheops, PLATO) and ground-based surveys will deliver an impressive number of new transiting exoplanets in the next decade.