UK Exoplanet Community Meeting 2022 Edinburgh

12-14 September 2022

Ashworth Laboratories Lecture Theatre 1
The King's Buildings
Edinburgh
UK

12th - 14th September 2022

SOC
Beth Biller (Edinburgh, Chair)
Amy Bonsor (Cambridge)
Raphaëlle Haywood (Exeter)
Nikku Madhusudhan (Cambridge)
Ken Rice (Edinburgh)
Amaury Triaud (Birmingham)

LOC
Beth Biller
Ken Rice
Thelma Dugdale
Lyndsey Ballantyne
Marrick Braam
Emma Bubb
Theron Carmichael
Maureen Cohen
Pengyu Liu
Larissa Palethorpe

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General Information

Relevant Links

The conference Zoom link is:

`https://ed-ac-uk.zoom.us/j/87154708081`

Meeting ID: 871 5470 8081

Poster presentations can be accessed at:

`https://padlet.com/thelmadugmore/jf3md8oe4ut5whm8`

Information for Speakers

We will be using Zoom to stream all talks. This means that you will be able to use your own device for your talk, but you must be logged in to the conference Zoom link while presenting. If you prefer, we will also be providing a Mac with OS X and a Windows machine for speakers to use. We can accommodate PDF, Keynote and Powerpoint. Please ensure you have uploaded and tested your talk on the computers prior to your session beginning, or have tested your own laptop/device with the Zoom link.

Speakers are encouraged to upload a copy of their talk slides here (either to use with the conference computers or as a backup):

`https://datasync.ed.ac.uk/index.php/s/fwjQW46vs9mHwf5`

Password: Exoplanet

All contributed talks are 12 minutes plus 3 minutes for questions, while highlight talks are 15 minutes plus 5 minutes for questions. Session chairs will give appropriate warnings when you are approaching your time limit. To ensure the smooth running of each session, please keep to time. Thank you!

Information for Posters

Posters will be entirely electronic for UKEXOM 2022. Poster presentations can be accessed at:

`https://padlet.com/thelmadugmore/jf3md8oe4ut5whm8`

Posters should have been submitted and circulated electronically ahead of the meeting. On the afternoon of 13 September, we will hold several parallel "Unconference" poster sessions, organised by topic. Your poster will be assigned to one of these sessions. Each session will open with 2-minute poster pop-up talks (up to two slides) for each poster assigned to that session, followed by general discussion and interaction within the session.

Online presenters will be able to present their slides on Zoom. Online attendees will be able to access the poster sessions via the main Zoom link, with breakout rooms set up for each poster session.

WiFi Access

The Kings Building Campus is equipped with EDUROAM for those that have access. Additionally, there is a visitor Wi-Fi service called Visit-Ed.

To access Visit-Ed:

- Look for 'Visit-Ed' under the available Wi-Fi networks on your device
- Tap Visit-Ed to connect
- Your device should launch the sign-in/registration page
- Complete the form and click Get Online

Social Media

#UKEXOM2022

"Unconference" session

On the afternoon of Tuesday 13 September we will hold an "unconference" session. There are a number of rooms booked in the James Clerk Maxwell Building (see King's Buildings map). There will be parallel sessions in which poster presenters will be given 2 minutes to present their posters. There will also be time for discussion in each session. There will also be an Extreme Precision Radial Velocity discussion session.

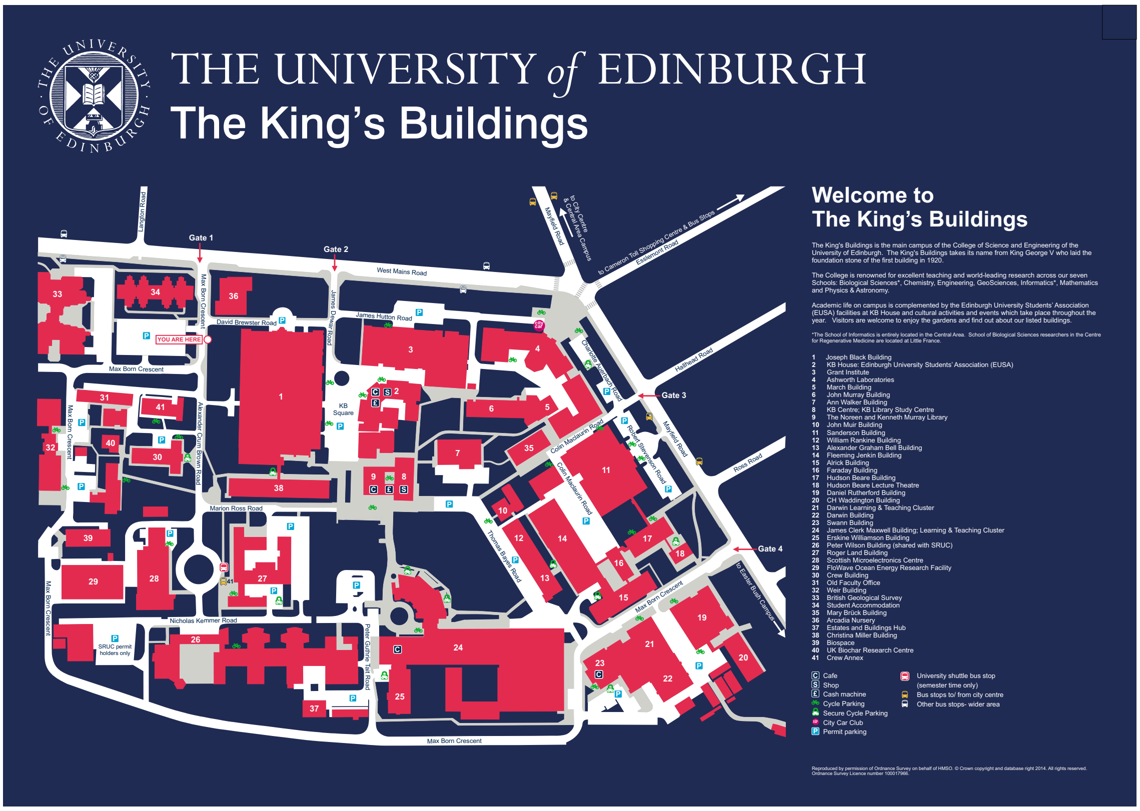
Covid Policy

The University of Edinburgh Covid restrictions have been lifted, however the following advice from the University of Edinburgh still encourages the use of face coverings:

> *"Face coverings are no longer legally required in indoor spaces, however the Scottish Government strongly recommends that you continue to wear a face covering in crowded and enclosed spaces. We encourage staff and students to continue to wear a face covering in indoor or communal areas on our campuses – for example in corridors, study spaces and libraries, on-campus shops, cafes and restaurants, unless seated to eat or drink – and when required for local health and safety practices."*

Given that UKEXOM 2022 will be bringing 100+ scientists from across the UK into close proximity for 3 days, we highly recommend wearing a face covering while in indoor settings at the conference. We will have a selection of surgical and FFP2 masks available at the registration desk, for those who want them.

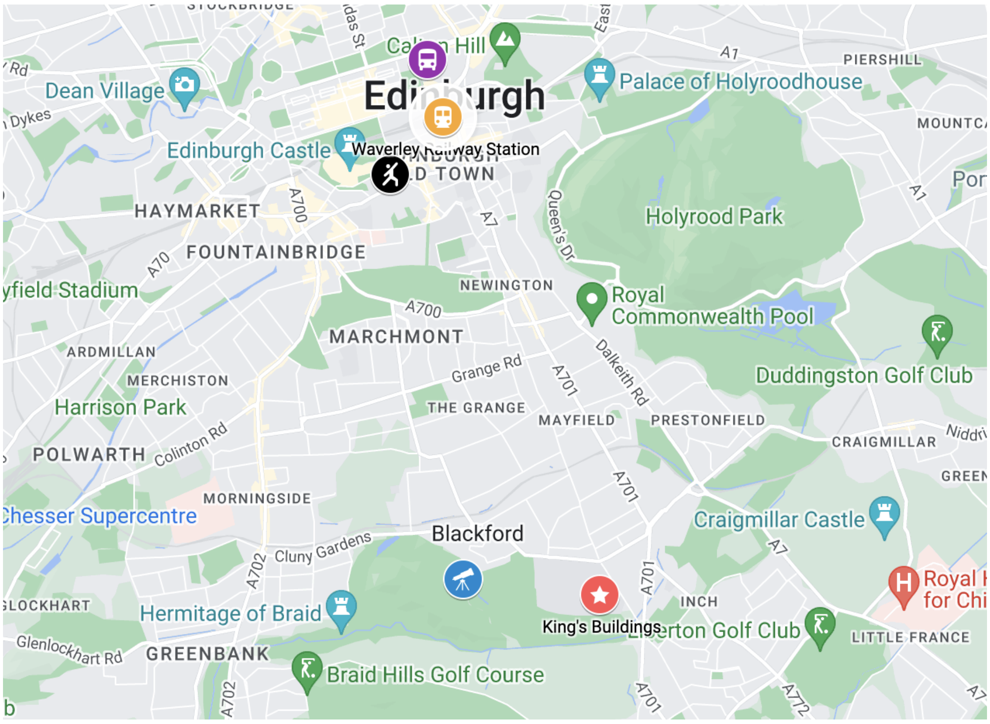
Conference venues



The conference will be held at the King's Buildings Campus of the University of Edinburgh. The talks will be in Lecture Theatre 1 in the Ashworth Laboratory (4). Coffee breaks, lunches, the "Unconference" afternoon, and conference dinner (both on Tuesday) will be in the James Clerk Maxwell Building (24). To reduce the carbon footprint of the meeting, all catering provided will be vegetarian. It is a 5-7 minute walk between the Ashworth Laboratory and the James Clerk Maxwell Building. Members of the Local Organising Committee will be on hand to help guide conference participants between the Ashworth Laboratory and the James Clerk Maxwell Building. However, be aware that weather in Edinburgh can change unpredictably – please do bring your umbrella / raincoat with you, as well as a jumper or jacket.

Link to Walking Directions between Ashworth Laboratories and JCMB

Getting Around Edinburgh



The map shows the King's Buildings (star), the Royal Observatory (telescope), Waverley train station (train), the main bus station (bus) and St Columba's Hall (dancer), where we'll hold the ceilidh.

The bus services in Edinburgh are generally rather good. Services run all around the city, and you can travel up to 26 miles from the city center on a "single" (£1.80) ticket. However, a "single" is only valid for a single trip on a single bus. If you plan to travel on more than one bus, you can buy a day ticket for £4.50. A day & night ticket, which costs £4.00, can be purchased after 6.00 pm. The 24 and 41 buses stop right at the Kings Building Campus. The 3, 7, 8, 29, 31, 37, 38, and 49 buses also stop close to the Kings Building Campus.

On Lothian buses, you can also use your contactless card, which will automatically work out the cheapest daily, or weekly, adult fare if you use it for multiple trips. If you want to use cash, you should have the exact fare. If you pay with a note, drivers will take it and keep your change! You can avoid this by using your contactless card, or by downloading the Lothian Buses app, which helps you plan your journey and allows you to download a ticket onto your phone - info here: `http://lothianbuses.com/getting-around/smartphone-apps`

A Lothian buses day ticket can also be used on the trams in the city zone, but cannot be used on the trams to get to, or from, the airport. The contactless price cap also doesn't apply on the trams.

Drivers only stop at designated bus stops - so be careful you aren't standing at the wrong stop!

Dining Options

There are many places to eat in Edinburgh. A small selection of some nearby and recommended places are listed below.

- The Salisbury Arms serves seasonal British food.

  `https://www.thesalisburyarmsedinburgh.co.uk/`

- A pub serving real ale and Edinburgh's largest nachos.

  `http://www.theauldhoose.co.uk/`

- Tanjore is a good South Indian restaurant.

  `http://tanjore.co.uk/`

- Voujon is another very good Indian restaurant

  `http://www.voujonedinburgh.com/`

- Isola is an Italian restaurant with a Sardinian flavour.

  `http://www.ristoranteisola.co.uk/home`

- Hanedan is a cozy Turkish restaurant near the central University campus.

  `http://www.hanedan.co.uk/`

- Located next to the Mosque, Mosque Kitchen provides good quality Indian food at a very reasonable price.

  `http://www.mosquekitchen.com/`

- Ting Thai Caravan is a casual diner serving South East Asian street food. If it happens to be full, Saboteur - Ting Thai's sister restaurant - is only a few doors away.

  `http://www.tingthai-caravan.com/`

- Hanams is a Kurdish grill house located near the Royal Mile.

  `https://www.hanams.com/`

- Henderson's is a very nice vegan and vegetarian restaurant in Tollcross, near the Bruntsfield Links.

  `https://www.hendersonsrestaurant.com/`

- The Nile Valley Cafe is a popular and inexpensive wrap place near the central University campus.

  `https://thenilevalleycafe.co.uk/`

Social Events

Ceilidh

On Monday evening there will be a ceilidh in St Columba's Hall, 14 Johnstone Terrace (see Edinburgh map above). The hall will open at 8pm, and the band will play from 8pm to 10:30pm, with a few breaks. There will be Scottish dancing, which you should be able to learn on the night.

There won't be any food, or drink, provided. However, you are welcome to bring any drinks or snacks that would like to share. We encourage everyone to help tidy up at the end of the night. Please contact exouk22@ed.ac.uk regarding Ceilidh tickets for friends and family who might wish to attend.

Conference dinner

On Tuesday evening there will be a vegan picnic dinner outside the James Clerk Maxwell Building (see King's Buildings map above). This will start at 18:00. There will also be drinks available in the Magnet Café, which is on the third floor of the James Clerk Maxwell Building. We will also be able to use the Magnet Café if the weather isn't suitable for eating outside. Please contact exouk22@ed.ac.uk regarding dinner tickets for friends and family who might wish to attend.

Useful Information

If you have any questions, please feel free to approach any member of the LOC during the conference, who will be happy to help. Alternatively, send an email to exouk22@ed.ac.uk, which will be monitored throughout the conference. For urgent matters, the LOC chair can be contacted on +44 (0)7913 312 227.

Emergency services	999
Local taxis	+44 (0)131 228 1211 +44 (0)131 777 7777 +44 (0)131 229 2468

Code of Conduct

The organizers of UKEXOM2022 are committed to making this meeting productive and enjoyable for everyone, regardless of gender, sexual orientation, disability, physical appearance, body size, ethnicity, nationality, or religion. We will not tolerate harassment of participants in any form. Please follow these guidelines:

- Behave professionally. Harassment and sexist, racist, or exclusionary comments or jokes are not appropriate. Harassment includes sustained disruption of talks or other events, inappropriate or unwelcome physical contact, sexual attention or innuendo, deliberate intimidation, stalking, and photography or recording of an individual without consent. It also includes offensive comments related to gender, sexual orientation, age, disability, physical appearance, body size, ethnicity, or religion.
- All communication should be appropriate for a professional audience of people from many different backgrounds. Sexual language and imagery is not appropriate.
- Be kind to others. Do not insult or put down other attendees.

Participants asked to stop any inappropriate behaviour are expected to comply immediately. Attendees violating these rules may be asked to leave the event at the sole discretion of the organisers without a refund of any charge.

Participants wishing to report a code of conduct issue, either as the affected individual or as an observer, may do so either by contacting a member of the LOC or by emailing: exouk22@ed.ac.uk.

Thank you for helping to make this a welcoming, friendly event for all![1]

[1] This code of conduct is adapted from the one used for the Cool Stars 20 conference in Boston; the latter was originally designed for an astronomy conference in London, adapted by Andrew Pontzen and Hiranya Peiris from a document by Software Carpentry, which itself derives from original Creative Commons documents by PyCon and Geek Feminism.

Talk Schedule

Start	End	Title	Presenter
		Day 1: Monday 12 September	
Start	End	Title	Presenter
09:00	09:10	Arrival and Welcome	
09:10	09:30	**Highlight talk -- Multi-dimensional GP models for stellar activity: lessons from HARPS-South**	Haochuan Yu
09:30	09:45	Refining Planetary Architectures and Characterising Surface Stellar Variability of WASP-166 and WASP-131 with ESPRESSO	Lauren Doyle
09:45	10:00	Detection of planetary signals in cases of extreme stellar activity	Oscar Barragán
10:00	10:15	Forecasting stellar activity for better exoplanet detection and characterisation	Lalitha Sairam
10:15	10:30	Photometric and spectroscopic stellar granulation signals as revealed by CHEOPS and ESPRESSO	Heather Cegla
10:30	11:10	Break	
11:10	11:30	**Highlight talk -- Diving into the AU Mic system: Planet masses- stellar activity and star-planet interactions**	Baptiste Klein
11:30	11:45	Recovering the structure of edge-on debris disks non-parametrically	Yinuo Han
11:45	12:00	Imprints of birth: how the birth cluster effects planetary architecture	Christina Schoettler
12:00	12:15	Planet formation around Circumbinary Stars	Gavin Coleman
12:15	13:40	Lunch	
13:40	14:00	**Highlight talk -- JWST Early Release Science: Exoplanet transit spectroscopy with NIRCam**	Eva-Maria Ahrer
14:00	14:15	Tantalising signs of H2O in the cloudy atmosphere of a warm Neptune from High-Resolution Spectroscopy	Spandan Dash
14:15	14:30	JWST Early Release Observation: A detailed look at the atmosphere of WASP-96b	Jake Taylor
14:30	14:45	**Spin-orbit alignment from transit photometry: the case for multi-colour observations**	Matthew Hooton
14:45	15:00	Carbon monoxide emission lines reveal an inverted atmosphere in the ultra hot Jupiter WASP-33 b and indicate an eastward hot spot	Lennart van Sluijs
15:00	15:40	Break	
15:40	16:00	**Highlight talk -- A Search for Longer-Period Transiting Exoplanets with TESS and CHEOPS**	Amy Tuson
16:00	16:15	SPECULOOS - Hunting for planets of very low-mass stars	Daniel Sebastian
16:15	16:30	Planet Hunters NGTS: No Planet Left Behind in the Next Generation Transit Survey	Sean O'Brien
16:30	16:45	Understanding long period planets with TESS and NGTS	Samuel Gill
16:45	17:00	Introducing Nomads- an observing program uncovering the origin of remnant planets in the hot Neptunian Desert	Ares Osborn
20:00	23:00	Ceilidh at St. Columba's Hall, 14 Johnstone Terrace (right off the Royal Mile)	
		Day 2: Tuesday 13 September	
Start	End	Title	Presenter
09:00	09:15	A miscellany of misalignments for planets transiting cool stars	Vedad Kunovac
09:15	09:30	Characterising the internal structures of small exoplanets with CHEOPS	Thomas Wilson
09:30	09:45	TOI-544b: a new small planet inside the radius valley	Hannah Osborne
09:45	10:00	Determining the occurrence rate of giant planets orbiting low-mass stars	Edward Bryant
10:00	10:15	The Antarctic Search for Transiting ExoPlanets	Georgina Dransfield
10:15	10:30	Current Status of the PLATO Mission	Don Pollacco
10:30	11:10	Break	
11:10	11:30	**Highlight talk -- Detecting Biosignatures of Nearby Rocky Exoplanets: Simulations of High Spectral Resolution Observations with the ELTs**	Sophia Vaughan
11:30	11:45	Detecting planetary mass companions near the water frost-line using JWST interferometry	Shrishmoy Ray
11:45	12:00	CRIRES+: Performance assessment for exoplanet spectroscopy	Måns Holmberg
12:00	12:15	The Impact of Various Modelling Assumptions on the Significance of High Resolution Cross Correlation Detections	Mitchell Young
12:15	12:25	Extreme Precision Radial Velocity discussion session pitch	Annelies Mortier, Heather Cegla
12:25	13:45	Lunch	
13:45	14:45	Parallel "Unconference" poster sessions, part 1	
		Atmospheres: Modeling	JCMB 4325A
		Planet Formation	JCMB 4325B
		Direct Imaging / White Dwarfs	JCMB 4325C
		Extreme Precision Radial Velocity discussion session	JCMB 5326
		Evaporation / Atmospheric Escape	JCMB 5327
14:45	15:45	Break	
15:45	16:45	Parallel "Unconference" poster sessions, part 2	
		Lightcurves and Transit Spectroscopy	JCMB 4325A
		Retrieval	JCMB 4325B
		TESS	JCMB 4325C
		Discs, Habitability and Tides	JCMB 5326
		Stellar Parameters / Activity	JCMB 5327
18:00	20:00	Conference picnic dinner in front of JCMB	
		Day 3: Wednesday 14 September	
Start	End	Title	Presenter
09:00	09:15	The extreme S-type binary planetary system DMPP-3	Adam Stevenson
09:15	09:30	Understanding planet formation through TOI-757 b- the eccentric transiting mini-Neptune discovered by TESS	Ahlam Alqasim
09:30	09:45	Characterising planets around iron-poor stars with HARPS-N	Annelies Mortier
09:45	10:00	Radial velocity and simultaneous magnetic field measurements via Multi-Mask Least-Squares Deconvolution	Florian Lienhard
10:00	10:15	A.C.I.D (Accurate Continuum fItting and Deconvolution) - An improved LSD technique for Rossiter-McLaughlin analysis	Lucy Dolan
10:15	10:30	Transmission strings: spatially resolving transmission spectra of exoplanet atmospheres around their terminators	David Grant
10:30	11:10	Break	
11:10	11:30	**Highlight talk - Using polluted white dwarfs to probe the bulk composition of exoplanets**	Laura Rogers
11:30	11:45	A White Dwarf Accreting Planetary Material Determined from X-ray Observations	Tim Cunningham
11:45	12:00	Can Gaia find planets around white dwarfs?	Hannah Sanderson
12:00	12:15	Understanding hot Jupiter atmospheric diversity with a large grid of 3D models	Alexander Roth
12:15	**13:40**	**Lunch**	
13:40	14:00	**Highlight talk -- Photoevaporation of Water Dominated Exoplanet Atmospheres**	Laura Harbach
14:00	14:15	Towards Coupled Modelling of the Biosphere and Atmosphere for the Archean Earth and similar exoplanets	Jake Eager-Nash
14:15	14:30	Inward transport of comets as a source of habitable zone dust	Jessica Rigley
14:30	14:45	Mineralogical limits to water budgets on rocky planets	Claire Guimond
14:45	15:00	Bayesian Network Analysis of Science Fiction Exoplanets	Emma Puranen
15:00	15:40	Break	
15:40	16:00	**Highlight talk -- A deep radius valley with Kepler short cadence data**	Cynthia Ho
16:00	16:15	The impact of stellar flares on the atmospheric composition of tidally locked terrestrial exoplanets	Robert Ridgway
16:15	16:30	Towards non-LTE Retrieval of Exoplanet Atmospheres	Sam Wright
16:30	16:45	Orbital influence on the 3-D atmospheric chemistry of Earth-like exoplanets	Marrick Braam

Talk Abstracts

Monday 12th September 2022

Session 1:

Multi-dimensional GP models for stellar activity: lessons from HARPS-South

09:10

Haochuan Yu[1]
[1] University of Oxford

Although instrumentations for measuring the radial velocities (RVs) of stars are approaching sub-meter per second accuracy, the detections of low-mass planets, i.e., Earth-analogues, are still very challenging. This is because the spotted- rotating stars can induce variations in the RV time-series roughly two orders of magnitude larger than the signals induced by possible Earth analogues. To overcome this, we use a multi-dimensional Gaussian Process (GP) framework to model the stellar activity signal using spectroscopic activity indicators together with the RVs. Particularly, a fast, newly-developed Marten 3/2 Exponential Periodic kernel (detailed in Delisle et al. 2022) is used in the GPs to enable rapid and robust analysis of a large volume of targets with sizeable data sets. We implement the framework on 366 best-observed targets from the HARPS data archive, investigating the effectiveness of modelling and mitigating activity signals in the RVs for stars of different spectral types, ages, and activity levels. Meanwhile, as tracked by the (hyper-)parameters in our activity model, we are able to accurately measure the rotation periods of the stars in our sample including a few slow rotators that would be hard to get from photometry, and explore indirectly how the spot to facular ratio varies across our sample. This work will provide valuable clues for planning future RV planet surveys such as Terra Hunting Experiment (THE), as well as contribute to fine-tuning the current stellar structure and evolution models.

Notes:

09:30 **Refining Planetary Architectures and Characterising Surface Stellar Variability of WASP-166 and WASP-131 with ESPRESSO**

Lauren Doyle[1]

[1] University of Warwick

Characterising a star in great detail is a vital tool for understanding exoplanets. This is because stellar physics can impact important exoplanet parameters such as radii, mass, and planet atmosphere determinations. Additionally, understanding stellar physics can be crucial when searching for low mass, long period planets (Earth-twins) due to signals being lost within stellar 'noise'. In this talk, I will present my most recent results on two transiting planets orbiting bright (V 10) host stars; (i) WASP-166 b, a transiting super-Neptune within the Neptune desert and (ii) WASP-131 b, a bloated Saturn mass planet. Utilising high-resolution spectroscopic transit observations from ESPRESSO of both targets, we apply the Reloaded Rossiter McLaughlin (RRM) technique to spatially resolve the stellar surface, characterising the centre-to-limb convection-induced variations, and refine the star-planet obliquity. The net convective velocity shift caused by granules changes as a function of limb angle (i.e. from the centre to the limb of the star) due to line-of-sight changes. Since WASP-166 is an F-type main sequence star (Teff = 6050 K), we were able to characterise centre-to-limb convective variations (CLV) as a result of granulation on the surface of the star on the order of a few km/s and explore differential rotation (DR). By accounting for CLV in our RM models, there was a difference in the star-planet obliquity of 10o- which is in agreement when compared to simulations. WASP-131 is a bloated Saturn-mass planet with a Teff of 6030 K. It also has a high star-planet obliquity of 157 deg making it an ideal candidate for determining CLV and DR. Therefore, we predict similar results which will be presented here for the first time.

Notes:

Detection of planetary signals in cases of extreme stellar activity 09:45

Oscar Barragán[1]

[1] University of Oxford

Active regions on stellar surfaces induce signals in radial velocity (RV) time series that limit our ability to detect planetary signals. In order to detect planetary-induced RV signals, we need to perform informed modelling of the stellar activity. The use of spectroscopic activity indicators is useful to understand the behaviour of stellar signals in RV data. However- the stellar activity manifests with different behaviour and shapes in different spectroscopic time series. Therefore, the use of activity indicators to inform the modelling of the stellar signal in the RV data has to be taken carefully. In this talk, I discuss how a multidimensional Gaussian Processes framework can be used to constrain the stellar signal in multiple spectroscopic time series. This approach takes into account the different shapes in which stellar activity appears in the spectroscopic time series. I will show some practical examples of how this approach has been used to detect planet signals tens of times smaller than the stellar signal for young active stars.

Notes:

10:00

Forecasting stellar activity for better exoplanet detection and characterisation

Lalitha Sairam[1]

[1] University of Birmingham

Stellar noise produced by magnetic activity such as flares, starspots, and plages mimics a low-mass exoplanet and creates spurious detections of atmospheric species. Although they are modelled for hindrance, stellar activity continues to affect detections by reducing the signal. Our ongoing project STellar ACtvity foreCAst for Optimal observations of exoplanets (STACCATO) is using forecasting models to predict the optimal time for exoplanet detection and the atmospheric characterisation of exoplanets reducing the need for stellar activity mitigation. In this talk- I will present how working hand in hand with stellar physics and exoplanetary science, we will significantly reduce the time taken by the observer to detect and characterise the exoplanets. By showing when to observe, I will demonstrate the synergy of STACCATO for ongoing and future missions such as HARPS3, ARIEL and PLATO.

Notes:

Photometric and spectroscopic stellar granulation signals as revealed by CHEOPS and ESPRESSO

10:15

Heather Cegla[1]

[1] University of Warwick

Variability on the surfaces of sun-like stars can mask and mimic exoplanetary signals and is currently the largest stumbling block on the pathway to the discovery and characterisation of temperate, rocky planets around such stars. At the most fundamental level, nearly all stellar surface variability is driven by the interplay between convection and magnetic fields. Here we will present the first analysis of spectroscopic and photometric signatures of stellar magnetoconvection/granulation for a bright G0V and an F7V star with high precision observations taken contemporaneously with CHEOPS and ESPRESSO. We analyse the statistical properties of the observed granulation and compare them to the Sun, as well as main sequence stars observed by Kepler and hydrodynamical simulations. We find consistent properties- which highlight the capability of both instruments to study this low amplitude stellar signal on short duration observations. These datasets also allow us to invalidate several relations that were empirically derived from past low precision surveys linking the photometric and spectroscopic observables while validating others. In the context of the upcoming PLATO mission and its dedicated radial velocity follow-up (necessary for mass determination and planet confirmation), we will comment on the impact of this stellar signal on both detection and characterisation of long orbital period exoplanets and present some potential avenues to mitigate these effects.

Notes:

11:10

Diving into the AU Mic system: Planet masses- stellar activity and star-planet interactions

Baptiste Klein[1]

[1] University of Oxford

Close-in planets orbiting low-mass pre-main-sequence stars are primordial targets, not only to understand the formation and evolution of planetary systems, but also to search for signatures of magnetic star-planet interactions- which offer a direct window on planetary magnetic fields. However, such stars exhibit intense magnetic activity inducing spectroscopic signals that overshadow potential planet signatures. As a result, only a handful of planetary systems younger than 25 Myr have been revealed so far without any detection of star-planet interaction in these systems. In this presentation, I propose to dive into the 22-Myr-old planet-hosting system AU Mic, intensively monitored in the optical with HARPS spectroscopy over the past few years. We used a state-of-the-art multi-dimensional Gaussian process to disentangle the 600-m/s stellar activity radial velocity signals from the signatures of the two recently-unveiled transiting planets. This allowed us to provide statistically-reliable mass measurements for AU Mic b and c. Surprisingly, planet c is found significantly denser than planet b, despite orbiting at larger orbital distance and, thereby, being less sensitive to stellar irradiation flux. We will discuss potential planet formation and evolution scenarios that could explain these observations. Additionally, we detect a significant modulation of AU Mic's non-radiative chromospheric flux at the period of AU Mic b. Using magneto-hydrodynamical simulations- we show that magnetic interactions between this planet and its host star's wind can produce the observed modulated emission power. Although more observations are needed, this could constitute the first direct detection of star-planet interaction in a young system.

Notes:

Recovering the structure of edge-on debris disks non-parametrically

11:30

Yinuo Han[1]

[1] University of Cambridge

The structure of debris disks carries an abundance of information. Radial features such as the sharpness of disk edges and substructures such as gaps may be indicative of embedded planets within a disk. Vertically- the height of a disk can constrain the mass of embedded bodies. Edge-on debris disks offer a unique opportunity to simultaneously access the radial and vertical distribution of material, however recovering either distribution in an unbiased way is challenging. In this talk, I present a non-parametric method to recover the surface brightness profile (face-on surface brightness as a function of radius) and height profile (scale height as a function of radius) of azimuthally symmetric, edge-on debris disks. This method not only avoids biasing the fitted profiles towards an assumed functional form, but also provides more realistic uncertainties on the underlying model given the observation. The method is applicable to thermal emission observations- but can also be applied to scattered light observations under the assumption of isotropic scattering. I present results from applying the algorithm to ALMA or mid-infrared observations of several debris disks, including AU Mic- Beta Pic and HD 61005. For each example, I compare our results with those from parametric studies in the literature and discuss the implications of the new structural information.

Notes:

11:45

Imprints of birth: how the birth cluster effects planetary architecture

Christina Schoettler[1]

[1] Imperial College London

Stars do not form in isolation but together with other stars, and often in a clustered environment. Depending on the initial conditions in these environments, such as initial density and substructure, the “closeness” of encounters between stars will differ. These encounters will not only affect the young stars, but also any protoplanetary discs and young planetary systems that are forming around them. In this talk, I will focus on the effect of the birth environment on young planetary systems. By combining the outputs of detailed N-body simulations that are calibrated to mirror different star-forming environments with long-term planetary integrations, I analyse the effects of typical flybys in these environments on planetary systems containing short-period Super Earths. I will present results of these investigations, showing that flybys can significantly modify the architecture of the planetary systems. I will also compare these results to the Kepler population commenting on whether the Kepler dichotomy (an apparent excess of single-transiting systems among Kepler systems) could be an outcome of birth environments with different initial conditions.

Notes:

Planet formation around Circumbinary Stars

12:00

Gavin Coleman[1]

[1] Queen Mary University London

In recent years numerous circumbinary planets have been discovered- just exterior to the dynamical stability limit. The formation processes of such planets remains an unsolved problem. Forming planets close to the stability limit has proven difficult to achieve due to large relative velocities that result from interactions with the central binary stars. Recent hydrodynamical simulations have shown that tidal torques from the central binary act to form eccentric cavities within the circumbinary discs typically extending just past the stability limit with the sizes and properties of such cavities depending on both the binary and local disc properties. One advantage of such eccentric cavities is that they act as barriers to planet migration due to positive pressure gradients. In this presentation I will present results on the evolution of circumbinary discs containing dust species of varying size and abundance. The effects of the dust not only on the disc but also on the implications for planet formation will be discussed. I will then present the results of Nbody simulations around circumbinary stars such as Kepler-16 and Kepler-34. These simulations include the formation of planet planets through either pebble or planetesimal accretion within a 1D viscously evolving circumbinary disc. The circumbinary disc includes 2D prescriptions for an eccentric precessing cavity based on results from hydrodynamical simulations. We also include prescriptions for photoevaporation planet migration and gas accretion. The results of such simulations show that the pebble accretion scenarios are able to produce planetary systems orbiting close to the central binary stars. In particular, simulations are able to produce planets akin to Kepler-16b and Kepler-34b.

Notes:

Session 2:

13:40

JWST Early Release Science: Exoplanet transit spectroscopy with NIRCam

Eva-Maria Ahrer[1]

[1] University of Warwick

The JWST Transiting Exoplanet Community Early Release Science (ERS) team is excited to share the first transmission spectrum observed by the NIRCam instrument. The observations of WASP-39b took place recently on 18 July 2022 and in this talk I will present the ERS JWST observations, which are all available to the community without proprietary period. This will include multiple independent analysis as done by the data analysis team and our conclusions on the behaviour of the instrument, as well as our resulting transmission spectrum of WASP-39b.The transmission group within the Transiting Exoplanet Community ERS team provides reduction and analysis methods for four transit observations of WASP-39b using different instruments and modes to cover a wide wavelength range in different spectral resolutions. This allows for a great case study to comparing features and systematics, as well as validating and studying methods. The ERS team also aims to provide resources such as open-source tools and recipe books for the community to analyse JWST data. Here we present the analysis of the WASP-39b transit as observed with the NIRCam instrument in its grism mode and using filter F322W2 with a spectral resolution of $R \sim 1000$, covering a wavelength range of 2.4-4.0 micron. This allows for detections of molecules such as water vapour, methane or carbon dioxide.

Notes:

Tantalising signs of H_2O in the cloudy atmosphere of a warm Neptune from High-Resolution Spectroscopy

14:00

Spandan Dash[1]

[1] University of Warwick

Characterization of cooler atmospheres of super-Earths and Neptune sized objects at low-resolution is often thwarted by the presence of clouds, hazes and aerosols which effectively flatten the transmission spectra. High-Resolution Spectroscopy (HRS) presents an opportunity to overcome this limitation by having the ability to detect molecular species whose spectral line cores extend above the level of clouds in these atmospheres. We analyse High-Resolution observations of the warm Neptune GJ 3470b taken over one transit using CARMENES ($R \sim 80400$) and two transits using GIANO ($R \sim 50000$) and look at the possibility of signature for first H2O in isolation and then H2O and CH4 together. We find a tentative detection of H2O using either the peak of the cross correlation signal or a cross-correlation-to-likelihood metric while comparing it to just the best fit model when all three nights are combined. The detection becomes even weaker when both H2O and CH4 are used for abundance and cloud deck layer values close to the best fit model. This decrease is in line with results from the Hubble Space Telescope at much lower resolution. However, accounting for the effects of data analysis on the compared model produces a strong detection close to the expected exoplanet position using just one night of CARMENES. Following this, we are planning to use a Bayesian retrieval tool to put simultaneous constraints on the abundance of molecular species and the pressure of the cloud top-deck. Such a tool will also allow us to directly compare/combine our results with published HST observations.

Notes:

14:15

JWST Early Release Observation: A detailed look at the atmosphere of WASP-96b

Jake Taylor[1]

[1] University of Montreal

The first exoplanet transmission spectrum the world saw from JWST was of WASP-96b using the NIRISS instrument. The initial description teased the atmospheric properties such as clouds and the presence of H2O molecules. As part of the Early Release Science collaboration we looked at this observation as a community. At least 4 individual data reductions of the planet were conducted, resulting in a consistent look at the transmission spectrum. Researchers from all over the world came together to lend their retrieval models and forward models to build a picture of the atmospheric processes on WASP-96b. In this talk I will discuss the data extraction and theoretical interpretation, highlighting how important it is to work as a community to better understand exoplanet atmospheres.

Notes:

Spin-orbit alignment from transit photometry: the case for multi-colour observations

14:30

Matthew Hooton[1]

[1] University of Cambridge

The asymmetric transit light curves of hot Jupiters orbiting fast-rotating early type stars encode information about the true spin-orbit angle ?: a parameter that eludes measurement using most other methods. However, an accurate measurement of ? using a transit is challenging with numerous values for individual planets in literature exhibiting significant disagreement. Doppler tomography provides an alternative spectroscopy-based method which is less prone to bias but only unlocks the sky-projected spin-orbit angle ?. I will present analyses of transit light curves for a sample of hot Jupiters with fast-rotating hosts acquired with CHEOPS, TESS, Kepler and Spitzer. The effect of fitting light curves acquired across the optical and IR with a single set of transit parameters greatly diminishes the degeneracies, and returns measurements of ? consistent with those from Doppler tomography. The placement of priors from tomography is better still, generally achieving improved precision on ?. With multi-colour light curves becoming available for ever-larger sections of the sky, this study provides a template for how to unveil the orbital architecture of these extreme systems and the underlying physical processes that shape them.

Notes:

14:45

Carbon monoxide emission lines reveal an inverted atmosphere in the ultra hot Jupiter WASP-33 b and indicate an eastward hot spot

Lennart van Sluijs[1]

[1] University of Oxford

Exoplanet atmospheres provide a unique window into their composition, dynamics as well as their formation and evolution pathways. The favourable star-planet contrast ratio of ultra hot Jupiters turns them into the ideal targets for atmospheric characterization with current observing facilities. Here we report the first detection of CO emission lines at high spectral resolution in the thermal spectrum of an exoplanet atmosphere. These emission lines, seen in the spectrum of the ultra hot Jupiter WASP-33 b, provide unambiguous evidence of a thermal inversion layer in its atmosphere, and are the first results from the MMT Exoplanet Atmosphere Survey. Moreover, by incorporating a Bayesian framework with 1D PHOENIX and 3D GCM atmospheric models, we show via Cross-Correlation-to-log-Likelihood mapping that the spectra indicate an eastward hotspot. Our resolution of R=15000 pushes the High-Resolution Cross-Correlation Spectroscopy method to its lowest resolution limits. This bodes well for systems that may require the use of lower resolution spectra to improve photon collection, such as small planets orbiting in the close in habitable zones of small, faint M-dwarfs.

Notes:

A Search for Longer-Period Transiting Exoplanets with TESS and CHEOPS

15:40

Amy Tuson[1]

[1] University of Cambridge

Detecting exoplanets via the transit method is inherently biased towards short-period planets. Due to the nature of its observing strategy- the Transiting Exoplanet Survey Satellite (TESS) is particularly susceptible to this detection bias; only 13% of planets confirmed by TESS have orbital periods longer than 20 days. It's crucial that we expand this sample of long-period planets to gain a more complete view of the exoplanet population. One way to do this is using duotransits; planet candidates with two observed transits separated by a large gap, typically two years. The true period of the duotransit is unknown, instead they have a discrete set of possible period aliases. We use these aliases to perform targeted follow-up of the duotransit with the CHaracterising ExOPlanets Satellite (CHEOPS) to recover the true period and ultimately confirm the planet. This allows us to find longerperiod planets than are typically found by the TESS mission alone. To select the optimal targets for our CHEOPS follow-up we have developed a specialised pipeline that searches for duotransits in the TESS data. We will present this duotransit pipeline and the results from our CHEOPS follow-up program so far. We have discovered 12 long-period exoplanets, including two planets in the TOI-2076 system, all of which have $P > 20$ days, $R_P < 5$ REarth and Gaia magnitude ¡ 12. Previously there were only 11 exoplanets discovered by TESS in this exciting parameter space, so our work has more than doubled the sample. These small, long-period transiting exoplanets are amenable to radial velocity follow-up and future atmospheric characterisation with the recently launched James Webb Space Telescope (JWST).

Notes:

16:00 **SPECULOOS - Hunting for plants of very low-mass stars**

Daniel Sebastian[1]

[1] University of Birmingham

The SPECULOOS survey is a transit-search survey, targeting a volume-limited (40 pc) sample of ultracool dwarf stars (spectral type M7 and later). The survey is powered by a global network of dedicated robotic 1 m telescopes, and its strategy leverages on the synergy with TESS for its brighter and earlier targets. Given its detection potential, once completed, it will not only provide terrestrial planets, well suited for atmospheric characterisation, but will also deliver robust constraints on the structure of planetary systems of ultracool dwarf stars. In this talk, I will detail the SPECULOOS project, its recent development, as well as its contribution to the detection and characterisation of planets orbiting low-mass stars.

Notes:

Planet Hunters NGTS: No Planet Left Behind in the Next Generation Transit Survey

16:15

Sean O'Brien[1]

[1] Queen's University Belfast

Planet Hunters NGTS is the next iteration of the Planet Hunters citizen science project-hosted on the Zooniverse platform. The project enlists public volunteers to search for exoplanet transits in data from the Next Generation Transit Survey (NGTS). NGTS is an array of twelve 20-cm telescopes at Paranal Observatory that have been observing since 2015- producing a rich dataset and the discoveries of 17 confirmed exoplanets so far. We aim to review the phase-folded light curves from the NGTS box least squares algorithm which identifies the strongest periodic signals, in order to find planet candidates that may have been missed in the initial review of the data. Volunteers are asked to classify the shape of any transit-like features in phase-folded light curves and whether there is any stellar variability or large data gaps in the image presented. The most promising candidates are then pushed to additional workflows where users check for secondary eclipses and whether the odd/even transit depths match. Since the project's launch in October 2021, over 3.5 million classifications have been made by more than 10000 volunteers. We will present the method implemented for combining multiple volunteer assessments together through a weighting scheme in order to identify potential new transiting exoplanets. We will report the preliminary findings and explore the detection efficiencies of the project by drawing comparisons with the catalogue of expert NGTS science team classifications. We will outline the ongoing vetting and follow-up of the most promising candidates from the project to date

Notes:

16:45

Introducing Nomads- an observing program uncovering the origin of remnant planets in the hot Neptunian Desert: survey strategy and early results.

Ares Osborn[1]

[1] University of Warwick

A key signature in the planet population is the hot Neptunian desert, a dearth of Neptune mass planets close to their host stars. The desert has been the subject of intense study as to its origin, and is thought to arise due to a combination of tidal disruption and photoevaporation. TESS has significantly increased the population of planets inside the desert ("nomads"), making a systematic study of the population of planets in the desert possible for the first time. One example of such a planet is TOI-849b, the remnant core of a giant planet. The new discoveries pose a key question: what formation and evolution pathways can leave a planet inside the desert-when such pathways are clearly not the norm? "Nomads" is a new program studying the nature and origin of the Neptunian Desert, aiming to double the current number of nomad planets in the desert that have precisely measured masses and radii, constraining their planetary densities and hence compositions. The resulting sample of characterised planets will provide the basis for theoretical studies of the processes that place planets inside the desert. In this talk, we will present an overview of the Nomads program, including the survey strategy and preliminary results. We will present new measurements of the planetary masses of several nomad planets, including an exciting new heavy Neptune, TOI-332.01, likely to be another remnant core akin to TOI-849b.

Notes:

Tuesday 13th September 2022

Session 3:

A miscellany of misalignments for planets transiting cool stars 09:00

Vedad Kunovac[1]

[1] Lowell Observatory

The obliquity of a star relative to the orbit of a transiting planet (the spin-orbit angle) has long been interpreted as a relic of the dynamical history of the system. The current literature sample has revealed that the spin-orbit angle distribution is stratified by stellar temperature. One would expect the temperature stratification to weaken as tidal evolution timescales increase, which would be the case for planets more widely separated from their hosts. I will present measurements of stellar obliquities for 13 cool stars hosting transiting planets in weaker tidal regimes than previously considered. These results are based on spectroscopic transits observed with the HARPS instrument, and overall we show that the distribution of obliquities for cool stars is more diverse than previously seen. Moreover- we use both archival and new radial velocities to better characterise the planetary eccentricities and additional unseen companions. This work represents the largest single contribution of stellar obliquity measurements of cool stars and casts new light on some recently seen patterns, such as the surplus of polar planets. Finally, I will present some ongoing efforts to characterise the obliquities of smaller planets with the EXPRES spectrograph at the 4.3-m Lowell Discovery Telescope.

Notes:

09:15

Characterising the internal structures of small exoplanets with CHEOPS

Thomas Wilson[1]

[1] University of St Andrews

The successful Kepler and TESS missions have discovered thousands of exoplanets and let the community focus on the characterisation of these bodies. One area of research utilises ultra-high-precision photometric and spectroscopic follow-up observations in order to accurately constrain the bulk densities of terrestrial exoplanets. Combining these observables with Bayesian internal structure modelling that uses geological equations of state, we can start to learn about the compositions of planets around main-sequence stars for the first time. Importantly, by studying multi-planet systems we can conduct comparative planetology that can reveal important aspects that challenge our knowledge of planet formation and evolution via the contrastment of the observational and modelling results of a planet against its neighbours. In this talk, I will present observational studies characterising multi-planet systems initially discovered with TESS and followed-up with ultra-high precision photometry from the recently launched CHEOPS satellite and ground-based RV instruments- such as HARPS and HARPS-N. Additionally, I will discuss our Bayesian internal structure and atmospheric escape analyses, and present the results of utilising such models on several key, multi-planet systems observed with CHEOPS, such as TOI-1064 and TOI-561, that are expected to become cornerstones of exoplanet characterisation due to the questions they raise about planet formation, the system multiplicity, or the amenability to atmospheric observations. Important knowledge about these new systems was uncovered via the refined radii, masses, and densities, a combination of precise observations using a new generation of instruments across different techniques, and cutting-edge planetary internal structure modelling. Therefore, utilising these resources we are at the beginning of a new era in characterising terrestrial bodies outside of our Solar System that will be strengthened with JWST.

Notes:

TOI-544b: a new small planet inside the radius valley

09:30

Hannah Osborne[1]

[1] University College London

TOI544b is a newly-characterised small planet (mass ¡ 4 Earth masses) recently detected with TESS and followed-up by the KESPRINT consortium. High-precision RV observations have allowed the mass of the planet to be constrained within 15% uncertainty and detect a previously-unknown longer-period companion with a mass precision of 10%, meaning these are some of the most precisely known exoplanet masses found using the RV method. The relatively low density of the inner planet puts it within a small subset of exoplanets which could be composed of mainly rocky silicates or water ices with or without layers of atmospheric hydrogen. However, the short orbital period means the effective temperature of this planet is above what would be expected for a rocky core to be able to sustain a hydrogen layer. We discuss the possibility of this planet joining the small group of 'ocean worlds' containing a significant fraction of water. As well as this, the planet sits firmly within the radius valley, a region where very few exoplanets are expected to be found. This, coupled with the high Transmission Spectroscopy Metric (TSM) and Emission Spectroscopy Metric (ESM) values make TOI-544b an excellent target for future atmospheric characterisation with the recently-launched James Webb Space Telescope and future Ariel mission. Finally, the importance of the TOI-544 system in relation to the wider population of small exoplanets and our understanding of planetary compositions will be presented.

Notes:

09:45

Determining the occurrence rate of giant planets orbiting low-mass stars

Edward Bryant[1]

[1] Mullard Space Science Laboratory

Determining the occurrence rate of giant planets orbiting low-mass stars (M ¡ 0.7 MSun) is a critical test of the core-accretion theory of planet formation (Laughlin et al. 2004). Results from previous surveys have poorly constrained the occurrence rate of these giant planets (e.g., Obermeier et al. 2016; Sabotta et al., 2021). In this study we will determine this occurrence rate using approximately one hundred thousand nearby ($d < 100$ pc) low-mass stars monitored in the TESS Full Frame Images (FFIs). We perform an automated transit search through light curves extracted from the TESS Full Frame Images for low-mass dwarf stars, selected using parameters from the TESS Input Catalog (TIC). Candidates are selected by a series of objective vetting steps that identify and reject false positive cases, particularly eclipsing binary systems and variable stars. Spectroscopic monitoring using high precision spectrographs, particularly ESPRESSO, is underway to determine the masses of our candidates, enabling us to confirm their planetary nature. Injection and recovery tests are being used to determine the detection efficiency of our survey, thereby enabling us to determine the frequency of giant planets around low-mass stars in a statistically robust manner. We will present our key findings and results from this project to data and discuss how our results impact the understanding of how giant planets form around their host stars.

Notes:

The Antarctic Search for Transiting ExoPlanets

10:00

Georgina Dransfield[1]
[1] University of Birmingham

Planets with long and/or infrequent transits present an observational challenge from the ground, as catching full events when limited by the day-night cycle relies to a large degree on luck. The challenge becomes even greater when transit timing variations (TTVs) are added into the mix, and often the result is that these fascinating systems can only confirmed by long-term radial velocity follow-up campaigns.However, these systems are the bread and butter of one telescope uniquely placed to observe them: ASTEP.ASTEP (Antarctic Search for Transiting ExoPlanets) is a 40cm telescope on the Antarctic plateau. ASTEP's proximity to the South Pole means that it enjoys outstanding photometric conditions, as well exceptional phase coverage due to uninterrupted observing for three months during the Austral Winter.Following a successful summer service mission, ASTEP began the 2022 observing season with a brand new two-colour photometer; this has broadened the range of targets ASTEP can observe to include cooler stars and shallower transits than ever before.In this talk, I will give an update on the status of ASTEP and showcase some of our most exciting results. These include the discovery and characterisation of the long-period three-planet system HD 28109 (TOI-282), which also features significant TTVs, as well as the first transit of a circumbinary planet observed from the ground.Planets with long and/or infrequent transits present an observational challenge from the ground, as catching full events when limited by the day-night cycle relies to a large degree on luck. The challenge becomes even greater when transit timing variations (TTVs) are added into the mix, and often the result is that these fascinating systems can only confirmed by long-term radial velocity follow-up campaigns.However, these systems are the bread and butter of one telescope uniquely placed to observe them: ASTEP.ASTEP (Antarctic Search for Transiting ExoPlanets) is a 40cm telescope on the Antarctic plateau. ASTEP's proximity to the South Pole means that it enjoys outstanding photometric conditions, as well exceptional phase coverage due to uninterrupted observing for three months during the Austral Winter.Following a successful summer service mission, ASTEP began the 2022 observing season with a brand new two-colour photometer; this has broadened the range of targets ASTEP can observe to include cooler stars and shallower transits than ever before.In this talk, I will give an update on the status of ASTEP and showcase some of our most exciting results. These include the discovery and characterisation of the long-period three-planet system HD 28109 (TOI-282), which also features significant TTVs, as well as the first transit of a circumbinary planet observed from the ground.

Notes:

10:15

Current Status of the PLATO Mission

Don Pollacco[1]

[1] University of Warwick

I will present the current status of the PLATO Mission which remains on target for launch in Q4 2026. Now that the flight instruments are being constructed, I can discuss the instrument performance and show you how you can become involved.

Notes:

Detecting Biosignatures of Nearby Rocky Exoplanets: Simulations of High Spectral Resolution Observations with the ELTs

11:10

Sophia Vaughan[1]

[1] University of Oxford

The imminent arrival of the Extremely Large Telescopes (ELTs) will finally deliver the observational power capable of assessing the habitability of nearby rocky exoplanets. The ELT presents us with the exciting opportunity of being able to spatially resolve the terrestrial exoplanet Proxima b, which lies in the habitable zone of Proxima Centuri. This would allow molecule mapping, a technique that uses the spatial separation plus cross correlation high resolution spectroscopy to disentangle the planet's spectrum from the host star and characterise its atmosphere. Here we present simulations in reflected light for the High Contrast Adaptive Optics (HCAO) mode of HARMONI/ELT, using model planet spectra from the Carl Sagan Institute designed specifically for Proxima b and its M-dwarf host star. HARMONI's resolution (R=17-385) is well suited to molecule mapping, with access to wavelengths covering multiple biosignatures. Our simulator shows that this first light ELT instrument can characterise the atmosphere of Proxima b, within a very reasonable time frame, but requires intervention on the focal plane masks in HARMONI's current instrument design. If changed, HARMONI has the potential to identify CO_2, CH_4, and H_2O in Proxima b. Our simulator is highly versatile and we are extending to other instruments for the ELTs, including METIS/ELT and GMagAO-X+IFS/GMT.

Notes:

11:30

Detecting planetary mass companions near the water frost-line using JWST interferometry

Shrishmoy Ray[1]

[1] University of Exeter

The recently launched JWST promises to be the finest infrared observatory for the next decade. Among its many instruments, the Near Infrared and Slitless Spectograph (NIRISS), when coupled with the Aperture Masking Interferometry (AMI) mask, will provide an unparalleled combination of sensitivity and angular resolution compared to any existing observatory in the mid-infrared wavelength region. Using simulated observations in conjunction with planetary evolution models, we present the capability of this mode to image companions around nearby stars at small orbital separations near the circumstellar water frost-line. This was done for the members of young, kinematic moving groups, Beta Pictoris and TW Hydrae and the association of Taurus-Auriga, using detection probability maps. We show that for appropriately chosen stars, JWST/NIRISS operating in the AMI mode can image sub-Jupiter companions near the water frost-line with a 68% confidence. Among these, M-type stars are the most promising. We also demonstrate that this JWST mode will improve the minimum inner working angles by as much as 50% in most cases when compared to the survey results from the best ground-based facilities.

Notes:

CRIRES+: Performance assessment for exoplanet spectroscopy 11:45

Måns Holmberg[1]
[1] University of Cambridge

High-resolution spectroscopy has proven to be a powerful avenue for atmospheric remote sensing of exoplanets. Recently, ESO commissioned the CRIRES+ high-resolution infrared spectrograph at VLT. CRIRES+ is a cross-dispersed spectrograph with high throughput and wide wavelength coverage across the near-infrared (0.95-5.3 microns), designed to be particularly suited for atmospheric characterisation of exoplanets. In this work, we report early insights into the performance of CRIRES+ for exoplanet spectroscopy and conduct a detailed assessment of the data reduction procedure. Because of the novelty of the instrument, we perform two independent data reduction strategies, using the official CR2RES pipeline and our new custom-built ExoRES pipeline. Using science verification observations we find that the spectral resolving power of CRIRES+ can reach R > 100-000 for optimal observing conditions. Similarly, we find the S/N to be consistent with expected and empirical estimates for the observations considered. As a case study, we perform the first application of CRIRES+ to the atmospheric characterisation of an exoplanet - the ultra-hot Jupiter MASCARA-1 b. We detect CO and H2O in the atmosphere of MASCARA-1 b at S/N of 12.9 and 5.3, respectively, and a temperature inversion revealed through the CO and H2O emission lines. Our findings demonstrate the scientific potential of CRIRES+ and highlight the excellent opportunity for high-resolution atmospheric spectroscopy of diverse exoplanets.

Notes:

12:00 **The Impact of Various Modelling Assumptions on the Significance of High Resolution Cross Correlation Detections**

Mitchell Young[1]

[1] University of Oxford

With the application of high-resolution spectroscopy to studying exoplanets, it is more important than ever to be able to accurately model the planetary atmospheres and associated spectra. But producing physically realistic models can be time consuming and computationally memory intensive, making them impractical for some applications. The alternative is to reduce the physical realism by incorporating simplifying approximations, such as assuming isothermal temperature profiles or LTE atmospheres. This raises the question of how this loss of physical realism affects the significance of results derived from using such models. Here, I present an investigation of how properly accounting for photoionization, atmospheric heating and cooling, and NLTE effects impacts the detection significance of Fe I in the atmosphere of WASP-121b during transit. Using the open-source code Cloudy, we modelled the atmospheric structures and transmission spectra of a number of WASP-121b-like planets, assuming varying degrees of physical realism, and cross-correlated the output with archival HARPS observations. We find that greater degrees of physical realism produce detections of greater significance- and that the different simplifying approximations do not all affect the detection significance equally.

Notes:

Wednesday 14th September 2022

Session 4:

The extreme S-type binary planetary system DMPP-3

09:00

Adam Stevenson[1]

[1] Open University

Stars are often found in binaries or higher multiples. Stellar multiplicity causes difficulties for the formation and retention of a planetary system, with the most hostile environments for circumprimary (S-type) planet formation being close-in and eccentric binaries [HW99- J-C15]. We will present recent HARPS radial velocity observations of DMPP-3, a highly eccentric binary star system ($e \sim 0.6$) where an object at the hydrogen burning limit, DMPP-3B, orbits the K0V primary DMPP-3A [B+20]. A 2.2 Earth mass planet, DMPP-3A b, has a 6.67 day orbit around the primary star. The binary semi-major axis is only 1.22 AU, making DMPP-3 by far the tightest known S-type system, challenging expectations. The architecture of DMPP-3 is unique among known RV-detected S-type planetary systems [S+21]. The new observations confirm the eccentric binary and DMPP-3Ab orbits. We have examined a long period RV signal- first identified in [B+20], concluding this signal arises from stellar activity. We also find (2% false alarm probability) a second S-type planet with mass $\sim$ 1 Earth mass [S+ in prep.]. The presence of a multi-S-type planet system in a highly eccentric close binary presents many opportunities to test and refine our models of planetary system evolution. References: [HW99] Holman Wiegert (1999) AJ, 117, 621; [J-C15] Jang-Condell (2015) ApJ, 799, 147; [B+20] Barnes+ (2020) NatAs, 4, 419; [S+21] Su+ (2021) AJ, 162, 272. [S+ in prep.] Stevenson+ (in preparation)

Notes:

09:15

Understanding planet formation through TOI-757 b, the eccentric transiting mini-Neptune discovered by TESS

Ahlam Alqasim[1]

[1] Mullard Space Science Laboratory

Mini-Neptunes are defined to have a radius larger than about 2 Earth radii but smaller than Neptune, and a mass between $\sim$ 5 and 40 Earth masses. The abundance of mini-Neptune planets that fall close to the radius valley (centered around Rp $\sim$ 1.8 Earth radii) has been challenging our understanding of planetary composition and formation. Eccentric mini-Neptune systems further complicate the scenario and challenge the evolutionary history of these planets. We report the properties of TOI-757 b, a mini-Neptune with a 17.5 day orbit transiting around TIC 130924120 (V = 9.7), discovered by the TESS mission. We acquired high-precision radial velocity measurements with the HARPS, ESPRESSO, and PFS instruments to confirm the planet detection and determine its mass measurement. We also acquired CHEOPS transit photometry to place stronger constraints on the planet radius. We present newly-constrained radius and mass measurements for the system, and we find that TOI-757 b is on an eccentric orbit (e = 0.43), which provides us with insights to the dynamical history of the system. The planet's high eccentricity is unlikely due to self-excitation, and rather suggests the possibility of gravitational interactions with another giant companion. Since mini-Neptunes appear to have a diversity of compositions, this target is favorable for atmospheric studies, which have the potential to break existing degeneracies in planet composition models, making it an exciting target for JWST.

Notes:

Characterising planets around iron-poor stars with HARPS-N 09:30

Annelies Mortier[1]
[1] University of Birmingham

To understand exoplanetary systems, we need to explore the full parameter space of stars and planets. One important parameter for planet formation and internal composition, is the stellar chemical composition. Kepler, K2, and TESS discover thousands of exoplanet candidates providing precise transit photometry which are then followed up by ground-based spectroscopy to characterise their masses and internal composition. In this talk I will give an overview of the HARPS-N Collaboration's leading efforts to characterise small planets, focusing on several recent results on small rocky planets orbiting stars with different chemical compositions than our Sun.

Notes:

09:45

Radial velocity and simultaneous magnetic field measurements via Multi-Mask Least-Squares Deconvolution

Florian Lienhard[1]

[1] University of Cambridge

To push the radial velocity (RV) exoplanet detection threshold, it is crucial to mitigate stellar activity. It has been shown that the hemispherically averaged unsigned magnetic flux is an excellent proxy for activity-induced RV variations. However, the stellar magnetic flux has not been measured to a sufficient precision for ground-based intensity spectra of FGK-type stars as of yet. In this talk, I will present a novel method to extract a proxy of the unsigned magnetic flux from HARPS-N solar spectra. This new activity index correlates with the hemispherically averaged unsigned magnetic flux as measured by SDO (Pearson correlation coefficient: 0.8) and RV variations on the magnetic cycle (Pearson correlation coefficient: 0.7) as well as the rotational timescale (Pearson correlation coefficient: 0.65) and in combination with advanced GP methods will pave the way to disentangle stellar and planetary signals in RV data and uncover the population of Earth analogues. Furthermore, the index may allow to measure the stellar magnetic cycle for stars without relying on single-line measures.

Notes:

A.C.I.D (Accurate Continuum fItting and Deconvoluton) - An improved LSD technique for Rossiter-McLaughlin analysis

10:00

Lucy Dolan[1]

[1] Queen's University Belfast

The Rossiter-McLaughlin (RM) effect can be better constrained when it is modelled across an entire line profile instead of only with the associated radial velocity shifts. However- current techniques used to extract line profiles, such as CCFs, risk contamination from neighbouring absorption lines that can effect the parameters extracted via modelling. Least-Squares Deconvolution (LSD) deconvolves the stellar spectrum to produce one high S/N 'mean' line profile and minimises this contamination from neighbouring lines by directly fitting the spectrum. However- LSD itself contains core assumptions which lead to over-estimations in the line depths of strongly blended lines as well as increased noise and distortion in the resulting profiles. We introduce our novel method ACID which directly addresses these issues to produce high precision line profiles from high resolution spectra. ACID builds on current LSD techniques by performing LSD in opacity space and simultaneously fitting the continuum and the - 'mean' line profile of each spectrum. Through application to synthetic data sets and analysing archival HARPS data for HD189733b, ACID is shown to be capable of delivering high S/N profiles that rival or exceed current CCFs. Our results highlight ACID as a useful technique in providing accurate line profiles from high-resolution spectra

Notes:

10:15

Transmission strings: spatially resolving transmission spectra of exoplanet atmospheres around their terminators

David Grant[1]

[1] University of Bristol

It is well established that planets exhibit three-dimensional variations in their atmospheric temperatures, abundances, and clouds. Yet exoplanets have long been treated as if they are uniform, not just in our retrieval models, but in our observations. This is particularly true in transit transmission studies where the light shining through the limb of the planet's atmosphere is measured as an average over the global terminator. Here we propose to advance upon this one-dimensional thinking by creating the first spatial map of the terminator of an exoplanet in transmission. We present a method for inferring the shape of the transmitting atmosphere, as a function of angle around the terminator, directly from the transit data. We define these shapes as transmission strings, and in these strings are imprinted the three-dimensional information about the planet's atmosphere. As the first observations with JWST begin,, and transit data reaches new levels of precision, the formalism we have constructed will enable us to create transmission spectra as a function of both wavelength and terminator angle. This will enable more detailed and less biassed inferences of exoplanet atmospheres than ever before.

Notes:

Using polluted white dwarfs to probe the bulk composition of exoplanets

11:10

Laura Rogers[1]

[1] University of Cambridge

Exoplanets are ubiquitous across the Milky Way, but finding out what the interiors of these planets are made from is challenging. At least 30% of white dwarfs are observed with signatures of swallowed exoplanets in their atmospheres. From these 'polluted' white dwarfs we infer the bulk composition of the parent body that was accreted. With over 1000 known polluted white dwarfs we can make powerful conclusions about exoplanetary composition and their geology. We present the first results from a new large survey studying some of the heaviest polluted white dwarfs. The composition of the planetary material that has 'polluted' the white dwarfs is inferred from their spectra. What can the composition tell us about exoplanetary material and geological processes in exoplanetary systems?

Notes:

11:30

A White Dwarf Accreting Planetary Material Determined from X-ray Observations

Tim Cunningham[1]

[1] University of Warwick

We have recently made the first direct detection of planetary material accreting onto a white dwarf using X-ray observations. This discovery, recently published in Nature, confirms G29—38, the prototype of all metal-polluted white dwarfs with detected debris disks, as a significant source of soft X-rays. Our detection relied upon a 106 ks exposure with the Chandra X-ray Observatory and provides the first direct evidence of ongoing accretion of planetary material onto a white dwarf. From the measured low-energy X-ray emission and modelled X-ray luminosity, we provide the first independent constraint on the accretion rate at such a system, finding an instantaneous accretion rate consistent with modelling of observed photospheric abundances. We measure a relatively low plasma temperature of kT $\sim$ 0.5 keV- corroborating the predicted bombardment solution for white dwarfs accreting at low accretion rates. I will present this recent discovery and its implications for the study of evolved planetary systems, including the accretion rates and bulk elemental compositions.

Notes:

Can Gaia find planets around white dwarfs?

11:45

Hannah Sanderson[1]

[1] University of Oxford

The Gaia mission is predicted to find thousands of planets with its high precision astrometry and could provide a new way to find white dwarf exoplanets. Only a few exoplanet candidates have been discovered around white dwarfs despite extensive direct imaging and transit surveys. Observations of planetary material 'polluting' the atmospheres of white dwarfs provide evidence that planetary systems exist around white dwarfs, but have yet to be linked to a planet detection. I present predictions of the number, mass and semi-major axis of planets that Gaia will discover around white dwarfs. Within this, I discuss the sensitivity of the Gaia telescope and how this relates to a possible white dwarf planet distribution predicted by simulations. How many planets will Gaia find around white dwarfs? What can it contribute to our understanding of post-main-sequence evolution of planetary systems?

Notes:

12:00

The Missing Sulfur Problem: Constraining the volatile sulfur abundance in the HD 100546 protoplanetary disk

Luke Keyte[1]

[1] University College London

Sulfur is one of the most abundant elements in the Universe, essential to astrochemistry and biological processes. Despite this, sulphur chemistry in star- and planet-forming environments is poorly understood. It is essential that we develop a deeper understanding of the volatile sulfur carriers in such regions, in order to build models that can meaningfully predict planetary composition. I present new observations of sulfur-bearing species in the HD100546 protoplanetary disk, which are interpreted through the use of complex thermochemical models. I explore the effect of varying C/O ratios on the modelled abundances, and provide new constraints on the total elemental sulfur in the disk. The results reveal widespread sulfur depletion from the gas-phase throughout the disk, indicating that the vast majority of volatile sulfur may be locked up into refractory species at an early stage.

Notes:

Session 5:

Photoevaporation of Water Dominated Exoplanet Atmospheres 13:40

Laura Harbach[1]

[1] Imperial College London

The atmospheres of close-in, low-mass exoplanets are extremely vulnerable to the effects of stellar UV to X-ray radiation. Photoevaporation can significantly ablate planetary atmospheres or even strip them entirely, potentially rendering a planet uninhabitable. Existing hydrodynamical studies of this important atmospheric mass loss mechanism have mainly considered hydrogen/helium dominated atmospheres. Currently, the effect of higher mean compositions on photoevaporative mass loss has only been the subject of a limited number of studies. In the era of more advanced exoplanet atmospheric observations, it is more important than ever to determine what, if any, atmosphere these planets may have been able to retain. Here, we present preliminary results of hydrodynamic simulations, showing a water-rich atmosphere of a low-mass planet undergoing photoevaporation. We show accurate modelling of higher mean molecular weight atmospheres can result in different escape rates than those predicted by current theoretical models.

Notes:

14:00

Towards Coupled Modelling of the Biosphere and Atmosphere for the Archean Earth and similar exoplanets

Jake Eager[1]

[1] University of Exeter

Life has played a key role in shaping the atmosphere since its origin on Earth and is likely to have played a similar role on inhabited exoplanets. However, modelling the biosphere's impact on climate is complicated by the range of time and spatial scales involved. 3D climate models have successfully been used to spatially resolve key processes, but on relatively short time scales. Whereas, biogeochemical modelling allows us to estimate biosphere driven gas fluxes in and out of the atmosphere over longer time scales, but lacks a sophisticated treatment of a spatially resolved atmosphere. Here, we look to bridge these two modelling approaches to better understand the biosphere's impact on the climate- and the possible implications this may have on terrestrial exoplanets. We use a biogeochemical model to understand the limits on the potential evolution of the atmosphere, as well as a state-of-the-art 3D climate model to explore potential atmospheric compositions produced by early biospheres. The biogeochemical model, coupled to a 1D photochemical model, has been developed to explore the effects of early biospheres driven by anoxic phototrophs. There is a particular focus on the effect of methane on the early climate, which has predominantly biotic sources. We then use the 3D climate model to explore the climate of varying plausible methane concentrations during the Archean. This work begins to explore how models of the early biosphere can be coupled to 3D climate models, to understand the biosphere's impact on the climate of Early Earth and potentially inhabited terrestrial exoplanets.

Notes:

Inward transport of comets as a source of habitable zone dust 14:15

Jessica Rigley[1]

[1] University of Cambridge

Warm exozodiacal dust clouds (known as exozodis) reside in the habitable zones of stars, and provide an opportunity to study the inner planetary system. An understanding of exozodis is also crucial to the detection of Earth-like planets, as they will obscure the habitable zones of stars. The presence of this dust has been found to correlate with exo–Kuiper belts, suggesting its origin lies further out in the planetary system. I will present a numerical model for the habitable zone dust produced by the inward transport of comets, which spontaneously fragment to produce dust. Dynamical simulations are used to follow comets as they are scattered inwards by interactions with planets. We follow individual comets as they undergo recurrent splitting events and produce dust, whose evolution is followed with a kinetic model that includes the effects of collisional evolution, Poynting-Robertson drag, and radiation pressure. With physically-motivated free parameters, this model is able to reproduce the size and spatial distribution of dust seen in the zodiacal cloud, supporting comet fragmentation as the plausible source of dust. Having tuned the model parameters to the Solar System, it can be applied to exoplanetary systems. I will apply the model to observations of the exozodi around eta Corvi, which has exceedingly high levels of habitable zone dust that are difficult to explain. I will show whether fragmentation of exocomets can supply enough dust to sustain its exozodi, and whether it can match the observed spatial distribution of dust.

Notes:

14:30

Mineralogical limits to water budgets on rocky planets

Claire Guimond[1]
[1] University of Cambridge

In rocky exoplanets as on Earth, the majority of the water resides on the inside. Two factors control the maximum mass fraction of "water" (as hydrogen) that a planetary mantle can store: its constituent minerals and its potential temperature. Experimental data is generally available on the temperature-dependent water saturations of common planet-forming minerals. Further, for a given exoplanet, mantle mineralogy can be predicted from the abundances of refractory elements in the host star. Hence the tools are in place to estimate the interior water capacities of hypothetical rocky exoplanets. This quantity represents the maximum amount of water that can be sequestered at the end of a planet's magma ocean stage, which, by having been stored in the silicate portion of the planet, will have been protected against early atmospheric loss and so can be outgassed to the surface. We present the distribution of interior water capacities of hypothetical planets orbiting known exoplanet host stars. We find that planets deep enough to stabilise Mg-perovskite almost invariably have a dry lower mantle, topped by a high-water-capacity transition zone which acts as a bottleneck for water transport within the planet's interior. The absolute mass of the wet upper mantle scales only shallowly with planet mass (as $Mp^{0.3}$) because the depth at which wadsleyite transitions to Mg-perovskite is roughly constant. Therefore, more massive rocky planets are expected to have disproportionately smaller mantle water capacities. This means that, for the same mass fraction of accreted water, a large portion of massive planets' water budgets would lie on the surface or in the atmosphere after magma ocean solidification. Their surfaces would be covered by either deep water-ice oceans or by arid rock; intermediate land/ocean fractions could be unlikely.

Notes:

Bayesian Network Analysis of Science Fiction Exoplanets

14:45

Emma Puranen[1]

[1] University of St Andrews

A new interdisciplinary approach applies Bayesian network analysis to a database of exoplanets from science fiction. The aim is to find connections between characteristics of the fictional planets, such as whether they support life, and astronomically-relevant pieces of information, such as whether the media featuring the exoplanet was published before or after the discovery of real exoplanets in 1995, in order to map the relationships between science and science fiction world-building. Statistics of the database of fictional exoplanets are presented, showing that fictional exoplanets are far more Earth-like than the real population of discovered exoplanets. The Bayesian inference software Banjo is used to create and analyse a Bayesian network, or a set of conditional dependencies between variables representing fictional exoplanet characteristics. Influence scores show that fictional exoplanets designed after the discovery of real exoplanets are slightly less likely to host intelligent life, and moderately less likely to host established human populations. This mirrors the real-life discoveries of a diverse range of exoplanets, many of which are far from human-habitable, and how these discoveries are affecting the world-building process of science fiction creators. Science fiction is the medium through which the public most often encounters exoplanets and is crucial for inspiring public interest in science, making the changing portrayal of exoplanets in science fiction of great interest to astronomers.

Notes:

15:40

A deep radius valley with Kepler short cadence data

Cynthia Ho[1]

[1] Mullard Space Science Laboratory

The structure of the radius valley (i.e. an observed lack of planets between 1.5-2 Earth radii) provides insights in planet formation and evolution theories. We present a new view of the radius valley, by refitting over 400 planets and updating their planetary parameters. We fit the planets homogeneously using Kepler 1-minute short cadence data, as over 350 planets in our sample have previously have their transits only homogeneously fitted with Kepler 30-minute long cadence data. We revise the radius valley and analyse its location dependence on various planetary and stellar properties including orbital period and stellar mas, as well as its emptiness. We find a deeper radius valley compared to several other studies, suggesting that planets are more likely to have homogeneous compositions at their formation than previously realised. We also observe a radius valley dependence on orbital period and stellar mass which is consistent with the core-powered mass loss model. This work also potentially indicates the benefits of light curves with shorter photometry cadences in relation to understanding exoplanet demographics.

Notes:

The impact of stellar flares on the atmospheric composition of tidally locked terrestrial exoplanets

16:00

Robert Ridgway[1]

[1] University of Exeter

The current best candidates for habitable exoplanets have been detected orbiting M-dwarf stars. Such stars are quite common, and their low brightness and the short orbital periods of their planets both aid observations. Many M dwarf stars are known to produce stellar flares, phenomena where the star releases substantial amounts of energy, particularly in the ultraviolet (UV) and becomes much brighter for a period of minutes to hours. In addition, flares are associated with a release of energetic protons from the star, known as stellar proton events. Flares released by the Sun are less energetic than those of M dwarfs. This presents some questions about the habitability of exoplanets around M dwarfs. The increased UV light and the protons may induce long-term changes in the exoplanetary atmosphere by destroying molecules such as ozone that help shield the surface from the UV. This would make the planet's surface dangerous for terrestrial life and may make the emergence and survival of surface-based life impossible. I present results from a study in 3D using the UK Met Office global circulation model, termed the Unified Model (UM). The UM has been adapted to model a wide range of exoplanets. I present the results from simulations including a coupled chemical kinetics and photolysis scheme. Our chemical network describes the production of ozone via the Chapman cycle as well as the change in ozone due to HOx and NOx photochemistry. A tidally locked aquaplanet with an Earth-like atmosphere is simulated for twenty years under quiescent conditions before it is subjected to a series of flares of varying total energies drawn from a realistic distribution. I will describe the changes in the atmospheric composition as well as surface habitability that occur due to the flares.

Notes:

16:15

Towards non-LTE Retrieval of Exoplanet Atmospheres

Sam Wright[1]

[1] University College London

As next generation observation facilities become available for the characterisation of Exoplanet atmospheres, the capacity to move beyond the assumption of molecules existing in local thermodynamic equilibrium becomes more pressing. While atmospheric retrieval of Exoplanet atmospheres has operated under this assumption, it is known that many effects within planetary atmospheres drive molecules away from this equilibrium, into a state of non-local thermodynamic equilibrium, or non-LTE. Here we revisit the bi-temperature model for approximating non-LTE molecule populations which uses a two temperature parameterisation: distinct rotational and vibrational temperatures. Here the implementation of this model is used in the molecular cross section generation code Exocross (Yurchenko et al. 2018) to further explore the differences arising in forward modelled spectra due to molecules existing in non-LTE. Now we include an exploration of non-LTE in the the optical with the additional consideration of Titanium Oxide (TiO),, this diatomic exhibits bands of accentuated intensity when in non-LTE. This can be seen in the figure shown here - forward model examples for TiO in the atmosphere of WASP-76b with 3 transit observations simulated for JWST's NIRSpec instrument set to use its G140H grating. In addition we show that the bi-temperature paramterisation is tractable for atmospheric retrieval. Here modifications were made to the publicly available atmospheric retrieval code TauREx 3 to include the additional temperature degree of freedom and non-LTE cross section data were generated using the Exocross code. This enables us to demonstrate the retrieval of both rotational and vibrational temperature parameters from JWST data simulated with under 10 transits.

Notes:

Orbital influence on the 3-D atmospheric chemistry of Earth-like exoplanets

16:30

Marrick Braam[1]

[1] University of Edinburgh

Determining the habitability and interpreting atmospheric spectra of exoplanets requires understanding their atmospheric physics and chemistry. Especially for the close-in orbits of terrestrial planets orbiting in the Habitable Zone of M-dwarfs, we can expect the existence of spin-orbit resonances. We use a 3-D coupled Climate-Chemistry model (CCM), the Met Office Unified Model with the UK Chemistry and Aerosol framework, to model the atmosphere of Proxima Centauri b. The chemical network includes the Chapman ozone reactions and the hydrogen oxide (HOx) and nitrogen oxide (NOx) catalytic cycles. We investigate the atmospheric chemistry for 1) a 1:1 resonant orbit, 2) a 1:1 resonant orbit with an eccentricity of 0.3, and 3) a 3:2 resonant orbit with an eccentricity of 0.3. In this talk, I will show that photochemistry driven by stellar radiation supports an ozone layer in all cases. Ozone profiles only fluctuate by up to one ppm between apo- and periastron since the dynamical timescales remain shorter than chemical timescales. Furthermore, the planet's spin can have implications for lightning-induced chemistry. In terms of habitability, a significant fraction of the planetary surface remains at temperatures suitable for the presence of liquid water and the ozone layer provides sufficient UV shielding in the range of orbits.

Notes:

16:45

Understanding hot Jupiter atmospheric diversity with a large grid of 3D models

Alexander Roth[1]

[1] University of Oxford

The hot Jupiter exoplanet population is extremely diverse, spanning more than an order of magnitude in instellation, atmospheric metallicity, gravity and rotation period. With the James Webb Space telescope and, later, Ariel mission providing wide wavelength coverage and ground-based telescopes supplying high resolution data, hot Jupiters will continue to be the best targets for atmospheric characterisation as we enter a new era of high-quality exoplanet observation. A hierarchy of atmospheric models have been used to model these planets- often trading modelling complexity for computational speed and cost. Yet, most of these planets are tidally locked and their atmospheres are intrinsically 3D, meaning that characterization with lower-dimensionality models can lead to biased inferences. Calculated using the state-of-the-art non-grey global circulation model SPARC/MiTgcm, we here present the largest library of 3D hot Jupiter models yet. This consists of 149 models spanning a wide range of instellation, metallicity, gravity and rotation periods typical for Hot Jupiters. Models including the strong photo-absorbing molecules TiO and VO are also calculated for higher instellations. In addition to systematically varying these parameters- we also vary them jointly, something which has not been incorporated in any previous studies to date. From these simulations, we calculate secondary eclipse spectra and phase curves to investigate how day-to-night heat redistribution and spectral properties vary with planetary parameters and identify any resulting qualitative trends.

Notes:

Poster Abstracts

Atmospheres and Modelling

Bistability of the atmospheric circulation on TRAPPIST-1e

Denis Sergeev[1]

[1] University of Exeter

The era of atmospheric characterisation of exoplanets is becoming imminent with the advent of the next generation of telescopes. In order to make the best use of future observational data, it is imperative to improve our theoretical understanding of exoplanet atmospheres and consider different dynamical regimes in which the atmospheres can reside. Using a 3D general circulation model, we demonstrate that a confirmed rocky exoplanet and a primary observational target, TRAPPIST-1e presents an interesting case of climate bistability. We find that the atmospheric circulation on TRAPPIST-1e can exist in two distinct regimes. One is dominated by a strong equatorial prograde jet and a large day-night temperature difference; the other is dominated by a pair of mid-latitude prograde jets and a relatively small day-night contrast. The circulation regime appears to be highly sensitive to the model setup, including initial and surface boundary conditions- as well as physical parameterizations of convection and cloud radiative effects. We focus on the emergence of the atmospheric circulation during the early stages of simulations and show that the regime bistability is explained by a delicate balance between the zonally asymmetric heating- mean overturning circulation, and mid-latitude baroclinic instability. The relative strength of these processes places our simulations on different branches of atmospheric evolution. The resulting steady state of the two regimes has differences in the amount of water content and clouds- affecting the water absorption bands and the continuum level in the transmission spectrum- but they are too small to be detected with the current technology.

Simulations of Clouds in the Atmosphere of GJ 1214b

Duncan Christie[1]
[1] University of Exeter

We investigate the impact of clouds on the atmosphere of GJ 1214b using the radiatively-coupled, phase-equilibrium cloud model EddySed coupled to the Unified Model general circulation model. We find that, consistent with previous investigations, high metallicity and clouds with large vertical extents are required to best match the observations, although metallicities even higher than those investigated here may be required to improve agreement further. We additionally find that in our case which best matches the observations, the velocity structures change relative to the clear sky case with the size of the nightside gyres increasing and a narrowing of the equatorial jet. The increase in cloud extentresults in a cooler planet due to a higher albedo, causing the atmosphere to contract. This also results in a reduced day-night contrast seen in the phase curves, although the introduction of cloud still results in a reduction of the phase offset.

Travelling planetary-scale waves on tidally locked exoplanets

Maureen Cohen[1]
[1] University of Edinburgh

Simulations of slowly rotating, tidally locked planets produce planetary-scale atmospheric waves often described as stationary. We show that these waves propagate backwards and forwards with a certain periodicity and describe the mechanism driving their time-dependent behaviour. The propagation of planetary-scale waves is associated with oscillations in cloud cover at the planetary terminators, as well as in surface temperature and other climatic parameters. We use simulation data from a 3-D general circulation model, the Met Office's Unified Model.

The Climate and Compositional Variation of the Highly Eccentric Planet HD 80606b

Shang-Min Tsai[1]
[1] University of Oxford

The gas giant HD 80606 b has a highly eccentric orbit (e $\sim$ 0.93) with stellar irradiation received by the planet spanning more than two orders of magnitude. The variation due to the eccentric orbit provides a unique opportunity to probe the physical and chemical timescales. Here, we present integrated models to study the atmospheric responses and the underlying mechanisms in detail. We first run 3D general circulation models (GCMs) of HD 80606 b for the thermal and dynamical structures. Based on the GCM output, we then use a 1D time-dependent photochemical model to investigate the compositional variation. Different sets of atmospheric metallicities and internal heating are explored. Our models show that efficient vertical mixing leads to deep quench levels of the major carbon and nitrogen species. Owing to the depth of the quench levels where the radiative timescale is long, the temperature variations have no effect on the quenching behavior throughout the orbit. Instead, photolysis and rapid heating in the upper stratosphere is the main driver of time-dependent chemistry. We find a transient state of [CO]/[CH4] ¿ 1 after periastron for all cases. The upcoming JWST Cycle 1 GO program will be able to track CH4 variations during the periastron passage and infer the chemical timescale. We found CO2 abundance peaked near transit- about 5 days after periastron. Lastly, sulfur species initiated by the sudden heating and photochemical forcing exhibit both short-term and long-term cycles, opening an interesting avenue for detecting sulfur on exoplanets.

Spatially-resolving the terminator: Variation of Fe- temperature and winds in WASP-76b across planetary limbs and orbital phase

Siddharth Ghandi[1]

[1] Leiden University

Exoplanet atmospheres are inherently three-dimensional systems in which thermal/chemical variation and winds can strongly influence spectra. Recently, the ultra-hot Jupiter WASP-76b has shown evidence for condensation and asymmetric Fe absorption with time. However, it is unclear whether these asymmetries are driven by chemical or thermal differences between the two limbs, as precise constraints on variation in these have remained elusive due to the challenges of modelling these dynamics in a Bayesian framework as well as the procurement of such high quality observations. To address this we develop a new model, HyDRA-2D, capable of simultaneously retrieving morning and evening terminators with day-night winds- and use this on recent high-precision terminator observations of WASP-76b with ESPRESSO/VLT. We explore variations in Fe, temperature profile, winds and opacity deck with limb and orbital phase. In this talk I will show that with HyDRA-2D we find Fe is more prominent on the evening for the last quarter of the transit. On the other hand the morning shows a lower abundance with a wider uncertainty, driven by degeneracy with the opacity deck and because the stronger evening signal dominates the overall spectrum. We also constrain a trend of higher temperatures for the more irradiated atmospheric regions, and a higher wind speed for the last quarter of the transit than the first. This new spatially, and phase-resolved treatment is statistically favoured by 4.9 sigma over traditional 1D-retrievals, and thus demonstrates the power of such modelling for robust constraints with current and future facilities.

The influence of a shallower- hotter- and spatially variable RCB on the atmospheric dynamics of hot Jupiters

Simon Lance[1]

[1] University of Exeter

Provisional results from 3D dynamical simulations of hot Jupiters show that with a shallower radiative convective boundary (RCB) and an increased internal heat flux we find a general weakening of the deep atmospheres zonal jet. One of the long-standing problems in the study of extrasolar giant planets is the anomalously large radii of highly irradiated gas giant planets compared to their expected size. A frequently proposed mechanism for this discrepancy is simply a hotter than expected interior adiabat driven by the vertical advection of potential temperature. When modelling such giant planet atmospheres- key lower boundary conditions such as the RCB pressure and intrinsic temperature Tint are commonly taken as being "Jupiter-like" in value. It has previously been shown however that the hotter interiors of these inflated hot Jupiters suggest much higher values of Tint and shallower RCBs. This work explores this "shallower and hotter RCB" regime- and I will present a number of simulations at a range of RCB depths and internal heat fluxes and highlight their effects on the dynamics of the overlying atmosphere- specifically on the commonly found feature of the observable atmosphere- the zonally circulating jet. Additionally- we go on to implement a spatially dependent Tint in an attempt to more accurately represent the convective flux that is likely to be found in such a planet. Ultimately this work is building towards a better understanding of the structure of the deep atmosphere- and therefore the overall structure of the planets and better explain their inflated radii.

Cloud modelling for transit spectroscopy

Sushuang Ma[1]

[1] University College London

There are clouds on almost all the sub-Neptunes and super-Earths that we detected so far. Current cloud model in transit spectroscopy is insufficient in the data oriented research with the next generation space telescopes (e.g. JWST and Ariel). Therefore- we aim at improve the cloud modelling for transit spectroscopy in the spectral retrieval and prepare for the future study of exoplanetary atmospheres.

Dynamical and RT effects resulting between NHD vs QHD in the THOR GCM

Pascal Noti[1]

[1] University of Bern

General circulation models (GCMs) play an important role in investigating atmospheres of exoplanets. GCMs often use various fluid dynamical approximations that lead to evolving different equation sets in time. Applying different dynamical equations for these atmospheres result in different atmospheric structures. Therefore, we investigate these effects in simulations of atmospheric dynamics using the GCM model THOR, where we compare the quasi-primitive dynamical equations and the full Navier-Stokes equations. We upgrade THOR with a non-grey "picket-fence", two-stream scheme for simulating the radiative transfer. We performed GCM simulations of a grid covering wide parameter range of orbital elements in the population of hot Jupiter exoplanets. First results show large differences in the magnitude and in the pattern of atmospheric parameters among simulations with varying dynamical equation sets.

Direct Imaging and White Dwarfs

Looking for planetary satellites around directly imaged substellar companions

Cecilia Lazzoni[1]

[1] University of Exeter

During the past years, the direct imaging technique has proven to be an extremely valid method to detect and characterize exoplanets. Coupling extreme adaptive optics with 8-meters class of telescopes, we can push the limits of detection to planets of a few Jupiter masses for young stars. Considering the mass and the separation at which directly imaged exoplanets are revealed the latter technique is suitable for the search of satellites. In this talk we will investigate the hunting of satellites around directly imaged planets, either with direct and indirect methods. Even if the detection of classic rocky moons still escapes our capabilities, with the upcoming arrival of instruments (from ground and space) we might be able to unveil such worlds. Also, more massive satellites might be common in exoplanetary systems and much easier to detect. I will then introduce the Negative Fake Companion Technique, developed to subtract the contribution of directly imaged exoplanets and brown dwarfs and to investigate their close surroundings for the presence of satellites. In this framework, the first Jupiter-like candidate satellite was discovered in the DH Tau system. Systems like DH Tau open up to a new category of mostly unknown planetary architecture, the "binary planets".

Exploring the Variability of Cloudy Brown Dwarf Atmospheres: The Case of WISE 1049 5319 AB

Emma Bubb[1]

[1] University of Edinburgh

Brown dwarfs and giant extrasolar planets display light curve variability around the L/T transition. This variability is possibly due to inhomogeneous clouds of silicate and iron condensates in the atmospheres of these objects. The presence of these patchy clouds creates a variation in the object's observed brightness as it rotates. Using a mixture of photometric methods and the Doppler Imaging technique we are studying the brown dwarf binary WISE 10495319 AB to gain a greater understanding of the top of atmosphere structure of these objects.

Variability survey of young and planetary-mass T dwarfs

Pengyu Liu[1]

[1] University of Edinburgh

Late spectral type brown dwarfs experience violent atmospheric changes as their temperature cools. Thick silicate clouds form and accumulate in L dwarfs' atmospheres. From late L to mid-T, these thick silicate clouds break up and condensate below the photosphere. Finally, it leads to a clear sky in the atmosphere of late T dwarfs. The cloud condensation causes top-of-atmosphere inhomogeneity on L and T brown dwarfs. Time-resolved variability monitoring reveals that field brown dwarfs indeed tend to be more variable in the L/T transition than out of the L/T transition. Dozens of young and low surface gravity brown dwarfs have been found in the past ten years. These young brown dwarfs have mass lower than $\sim$20 Mj and are directly-imaged giant planet analogs. Compared with field brown dwarfs, they have redder colour, indicating thicker clouds in their atmosphere. A survey of young L dwarfs has found that young L dwarfs are more variable than their field dwarf counterparts. As a continuing study of that survey, we are conducting another time-resolved photometric variability monitoring of young planetary-mass objects from late L to late T. We are going to investigate if the young L and T dwarfs are more variable than the field L and T dwarfs, and if they also tend to be more variable in the L/T transition than out of the L/T transition. Our survey result will increase our understanding of how the surface gravity influences the atmosphere of L and T dwarfs and also increase our understanding of the atmosphere of planetary-mass objects.

Variability and 3D cloud structure on isolated brown dwarfs and giant planets

Xianyu Tan[1]

[1] University of Oxford

Observations of brown dwarfs (BDs), free-floating planetary-mass objects, and directly imaged extrasolar giant planets (EGPs) exhibit rich evidence of large-scale weather. It has long been suggested that clouds play a critical role in shaping the weather system in these worlds, and theoretical efforts on understanding their three-dimensional (3D) structures are under investigation. In this talk, I will introduce a mechanism invoking cloud radiative feedback as a major driver for the 3D structure and circulation in the atmospheres of these objects. I will show that this mechanism can generate vigorous atmospheric flows, including turbulence, vortices, waves, and zonal jets under certain circumstances. Lastly, I will present preliminary results using state-of-the-art 3D models that incorporate realistic radiative transfer and cloud formation, showing the effects of 3D cloud structure on the emerging spectra and spectroscopic variability.

Velocity imaging the rapidly precessing planetary disc around the white dwarf HE1349-2305

Christopher Manser[1]

[1] Imperial College

A large fraction of planetary systems will survive the evolution of their host star to the white dwarf phase- observed largely via the pollution of white dwarf photospheres by planetary material. This material is thought to arrive most commonly via planetesimals that arrive to the white dwarf Roche radius from highly eccentric orbits, become tidally disrupted and form compact ($\sim$1 Solar radius) discs of dust. A rare subset of these dusty discs host gaseous material observed via the Doppler-broadened double-peaked line emission from atomic transitions, most notably the 860nm calcium triplet. In this talk, I will introduce one such system, HE1349-2305 where the emission from a gaseous debris disc displays rapid morphological changes indicative of precession of the disc. Through spectroscopic monitoring spanning three years, we have produced a Doppler tomogram of this disc revealing the structure of the emitting material in velocity space. I will discuss the interpretation of this structure, how this compares with the only other white dwarf planetary disc velocity-imaged, and what we can learn from these velocity-images.

Sunbathing under a white sun - modelling WD-BD systems

Elspeth Lee[1]

[1] University of Bern

White-dwarf - Brown dwarf systems represent the extremes of the populatoion of irradiated atmospheres due to their large external and internal heat combination. In this submission, I will present recent work improving the 3D modelling of these systems, including a new correlated-k RT approach for modelling these atmospheres. Focusing on 3 well observed systems, I will compare our 3D GCM modelling to observational data. These fascinating systems offer observers and theorists a chance to explore the extreme side of exoplanetary atmospheric science.

New insights into the PHL5038AB system

Sarah Casewell[1]
[1] University of Leicester

We present new results on PHL5038AB, a detached white dwarf-brown dwarf binary (Steele et al., 2009) comprising a hydrogen rich DA white dwarf and a L8 brown dwarf. The white dwarf is cool, with an effective temperature of ∼7750 K and a mass of 0.56 $M_{\odot}$. In order to begin orbital monitoring of PHL5038AB we obtained K band imaging using NIRI on Gemini North. The images resolve the binary and show the separation of the components is ∼ 66 AU. However it is very likely the system formed with the brown dwarf in an orbit similar to that of Neptune. When the white dwarf progenitor evolved into a white dwarf ∼1.22 Gyr ago the system became wider. Surprisingly, PHL5038A also shows signs of metal pollution via Ca II lines in its optical spectrum, although the detected infrared excess is consistent with that of a brown dwarf alone. This is only the second metal polluted white dwarf known with a brown dwarf companion, and unlike SDSSJ155720.77+091624.6 (Farihi et al. 2017), the brown dwarf is widely separated. Such metal pollution could suggest there are rocky bodies in the system that are being disrupted by the brown dwarf and then being accreted by the white dwarf.

Substellar Dynamical Masses: Progress Precision, Validations Vexations

Trent Dupuy[1]
[1] University of Edinburgh

The strongest tests of substellar evolutionary models require measurements of the fundamental parameters of mass and/or age. In the third decade of observational brown dwarf science that we are currently in, there has been major progress in using high-precision mass benchmarks to distinguish between competing substellar models. Binary brown dwarfs with individual dynamical mass measurements serve as "mini-clusters" to probe the luminosity/temperature evolution of brown dwarfs, and I will present new results for epsilon Indi Bab, which now has the highest-precision masses of any brown dwarfs (0.5% uncertainties). epsilon Indi Bab confirms previous evidence that cooling slows during the L/T transition, for the first time in a system with a post-L/T-transition component. Gaia astrometry as opened the door to precise mass measurements of substellar companions on wide, centuries-long orbits. While this blossoming of dynamical mass results has often validated the predictions of existing models, not all measurements are in harmony with theory, with some brown dwarfs seeming to be too massive and other not massive enough. In the fourth decade of brown dwarf science to come, our ongoing orbit monitoring of the coldest brown dwarfs will offer the chance of more validations, or vexations, for objects approaching planetary masses (∼10-20 M_{jup}).

Discs, Habitability and Tides

Clear-out of photoevaporating protoplanetary discs via radiation pressure

Alfie Robinson[1]

[1] Imperial College London

The current understanding of protoplanetary disc dispersal involves the removal of gas and dust via a photoevaporative wind generated by stellar heating of the disc. Previous models implied that there should be a large population of non-accreting discs with inner cavities due to the length of time needed to clear the outer disc. However, a lack of observations of such discs suggests that this clear-out must occur on shorter timescales. Work done by Owen & Kollmeier (2019) showed that these short timescales could be achieved by the removal of the dust component of the disc via radiation pressure from the central star. I am continuing this work by moving to a 2D framework that will incorporate a self-consistent calculation of the dust particle distribution in order to more accurately determine dust mass-loss rates. If the clear-out timescale remains short, this will support the conclusion that a combination of photoevaporation and radiation pressure mechanisms can lead to disc dispersal that fits the observational constraints.

Forming Extreme Debris Disks with Giant Imapcts

Lewis Watt[1]

[1] University of Bristol

Our work focuses on understanding why extreme debris disk observations are rare assuming giant impacts are ubiquitous. We focus on trying to explain why some disks, like ID8, show a steady increase in flux after a large drop off. We conduct a multi-stage numerical campaign. We begin by simulating giant impacts using a smoothed particle hydrodynamical code- modeling our planets using tabulated equations of state for two materials; forsterite for mantle and iron for core. From the collisions- we track the distribution of vapour and melt material. We assume that the vapour will condense into the smallest grain sizes while the melt will form the background km-sized planetesimal population that will sustain the disk. We then follow the spatial and collisional evolution of the planetesimals formed from the impact using the N-body code Rebound. We show that the collisions between planetesimals in the post giant impact disk can add a substantial amount of small grains into the disk. The number of collisions in a disk is heavily dependent on the position of the disk from the star- with an increase in collisions closer to the star. The number of collisions is also found to vary with orientation of the giant impact if the escaping material from the giant impact has an anisotropic distribution. We find boulder populations are more effective at increasing the flux in a disk closer to the central star.

Warping Away Gravitational Instabilities in Protoplanetary Discs

Sahl Rowther[1]

[1] University of Warwick

In their youth- protoplanetary discs are expected to be massive and self-gravitating, which results in non-axisymmetric spiral structures. However recent ALMA observations of the midplane of young protoplanetary discs show a lack of spiral structures. Instead, axisymmetric discs with some also having ring & gap structures are more commonly observed. Additionally, there are an increasing number of observed discs that are thought to be warped or misaligned. Common mechanisms of warps include flybys and misaligned infall, both being more likely in the early stages of a disc's evolution when it is still in a clustered environment and has plenty of material still infalling. We perform 3D SPH simulations of warped- non-coplanar gravitationally unstable discs to show that as the warp propagates through the self-gravitating disc, it heats up the disc rendering it gravitationally stable. Thus losing their spiral structure and appearing completely axisymmetric, potentially resolving the discrepancy between observations and theoretical predictions.

The Effects of Orbital Eccentricity on Habitability of Earth-like Planets

Binghan Liu[1]

[1] University of Leeds

Terrestrial exoplanets with a higher eccentricity than Earth are exceptionally, common in the Universe. Contrary to the eccentricity distribution of rocky planets in our solar system- there are more than 16 percent of currently measured rocky exoplanets have eccentricity greater than 0.2 according to The Extrasolar Planets Encyclopaedia (Mercury, which harbours in the most eccentric orbit in our solar system, has eccentricity about 0.2). In recent decades, there has been a growing interest in studying how orbital configuration affects terrestrial exoplanets' habitability. The climate response to higher orbital eccentricity than Earth's is not well-understood because of the interplay between both eccentricity and obliquity, assuming a fixed longitude of perihelion. To understand how eccentricity may influence the climate of an Earth-like planet, we employ the 3D Earth climate model WACCM 6 as our simulation tool to study the climate response in terms of atmospheric escape rate, water loss and fractional habitability to varying solar forcing due to higher eccentricity.

Accurate UV stellar spectra measurements required to use O3 as an indicator for O2 abundance

Gregory Cooke[1]
[1] University of Leeds

Terrestrial exoplanets around M dwarf stars are numerous and potentially habitable. However, hypothesised biosignatures such as O2 may not be easily detectable in their atmospheres. Atmospheric O3 has been proposed as an indicator of atmospheric O2 abundance, and in many cases could be easier to detect. The ultraviolet (UV) part of the stellar spectrum controls the chemistry and thus composition of terrestrial atmospheres, influences the observability of important gases such as O3 and CH4, and is required to evaluate an exoplanet's potential habitability. However, the UV spectrum of many exoplanet-hosting M dwarf stars is poorly constrained. Using WACCM6, a 3D Earth System Model, we explore how uncertainties in stellar spectra- specifically in the UV, can affect the atmospheric state of terrestrial tidally locked exoplanets. Starting from the same initial conditions, we then introduce two different stellar spectra that have been proposed to represent the same M dwarf star. We use the Planetary Spectrum Generator to show how the molecular signatures of these two atmospheres in synthetic observations are very different. Without accurate knowledge of the host star's UV spectrum, we discuss how the interpretation of future observations- especially of O3 and how it relates to the abundance of O2, will be ambiguous. In order to use O3 as an indicator for O2 abundance, our results further motivate the need for future missions that are able to accurately constrain the stellar UV spectrum of exoplanet host stars.

Impact of convective inhibition on hydrogen runaway greenhouse atmospheres

Hamish Innes[1]
[1] University of Oxford

The inner edge of the habitable zone is typically calculated as the maximum instellation a planet can receive and still maintain a surface ocean. Above this threshold, atmospheres enter a moist runaway state where increases in surface temperature are no longer compensated by increases in OLR, leading to the boil-off of oceans and loss of water to space via escape mechanisms. In classical calculations of the runaway greenhouse effect, atmospheres are assumed to be on a moist adiabat in the deep atmosphere due to convective mixing. We reexamine the convective assumption for hydrogen-dominated atmospheres, where condensation-induced vertical gradients in composition can significantly reduce buoyancy and shut off convection. Thus, the lapse rate in these regions is set by radiative equilibrium, which in optically thick atmospheres is much larger than the convective rate. We show- using a 1D radiative-convective model, that the resulting OLR is reduced due to a decrease in the temperature in the upper atmosphere. This reduction in OLR corresponds to a decrease in the inner habitable zone threshold instellation and limits the range of instellations hydrogen-dominates super-Earths or sub-Neptunes can receive whilst hosting a temperate surface ocean.

Tidal dissipation in Jupiter Saturn using models informed by Juno and Cassini

Adrian Barker[1]

[1] University of Leeds

The observed orbital migration of the moons of Jupiter and Saturn in our solar system imply efficient dissipation of tidal flows inside these giant planets. The mechanisms responsible are not well understood. The latest observational constraints from both the Juno and Cassini missions suggest that the interiors of Saturn and Jupiter contain extended regions that are stably stratified (stable to ordinary convection), but the importance of such stable layers on their tidal flows has not been fully explored. In this talk I will present the results of new theoretical models containing stable layers similar to those constrained observationally for Saturn (and hypothesised for Jupiter), to explore the dissipation of tidal flows inside these giant planets. The presence of an extended stably-stratified core can significantly enhance the tidal excitation of inertial waves (due to rotation) in the convective envelope. I will demonstrate that efficient tidal dissipation rates, which are sufficient to explain the observed migration rates of the moons, are predicted at the frequencies of the orbiting moons due to the excitation of inertial or gravito-inertial waves (gravity waves influenced by rotation) in these models. I will also discuss the application of these results to the orbital circularisation rates of hot and warm Jupiters and hot Neptunes.

Tidal dissipation in Hot Jupiters due to elliptical instability

Nils de Vries[1]

[1] University of Leeds

Tidal dissipation circularises orbits and synchronises spins of close-in planets. One mechanism responsible could be the elliptical instability- which occurs in strongly tidally-deformed Hot Jupiters (represented by their ellipticity ϵ). This instability is invoked in convective regions of planets but its interaction with turbulent convection has not previously been studied. I will present a new study of the interaction of the elliptical instability with convection using simulations in a local box model to explore its resulting tidal dissipation. We find that convection can significantly modify the outcome of the instability- leading to an enhanced and steady energy transfer from the tidal flow- unlike the very bursty behaviour obtained from the elliptical instability in isolation. This new regime has a weaker scaling with ϵ and so could be important for wider orbital periods. We quantify the tidal dissipation rates resulting from this instability, which we use to calculate tidal evolutionary timescales (for circularisation and synchronisation), assuming our results hold for realistic planetary parameters that are inevitably computationally inaccessible. We show that this mechanism can potentially be important for the closest hot Jupiters. We also indicate that bursts of elliptical instability can transport heat even in stably stratified surface radiative layers of these planets.

Evaporation and Atmospheric Escape

Thermal Evolution of Catastrophically Evaporating Planets

Alfred Curry[1]
[1] Imperial College London

Possibly the most extreme rocky planets discovered are a number that orbit so close to their main sequence host stars that their surfaces are not only molten but undergoing evaporative mass loss. We observe these systems through the highly variable and distinctively shaped tails produced by this material. In this work we aim to model the evolution of these catastrophically evaporating planets. The basis is a 1D interior code, similar to stellar structure codes, able to deal with the thermal processes, including melting, in the underlying planet. This will then be coupled to a wind describing the mass loss. Apart from being fascinating in their own right, catastrophically evaporating planets also provide an opportunity to study the composition of rocky planet interiors, as it is this material that makes up the observed tails. Full evolutionary modelling is important because the composition is temperature and pressure, and thus time, dependent.

Using Lyman-Alpha Transits to Test Atmospheric Escape Models

Ethan Schreyer[1]
[1] Imperial College London

In the past decade it has become clear that atmospheric escape plays a significant role in the evolution of exoplanets, particularly for small planets. Lyman-Alpha transit spectroscopy is one of the most successful methods used to observe atmospheric escape. However difficulties in interpreting the resulting spectrum means that it has not been utilised to conclusively constrain atmospheric escape models. Contamination of the spectrum by absorption of Lyman-Alpha radiation in the interstellar medium and geocoronal emission from the Earth's exosphere makes meaningful transit detections only available in the line wings of the spectrum. 3D hydrodynamics simulations show that the outflow that is being observed in these line wings is determined by the interaction of the escaping planetary gas and the circumstellar environment. These have been somewhat successful in reproducing the features seen in observations, however due to computational constraints it is not possible to run these over a large range of parameters. This is especially important as key parameters such as the stellar wind and EUV output of stars is poorly constrained. In this talk, I will present a semi-analytic model of the interaction between the escaping gas and the circumstellar environment motivated by the results of 3D hydrodynamics simulations which (1) approximates the outflow to the required level of accuracy to compare to observations and (2) is computationally light enough to perform a rigorous parameter study in order to constrain important escape parameters and models of atmospheric escape.

The photoevaporation history of three planets around K2-136

Jorge Fernandez[1]
[1] University of Warwick

I present an X-ray evaporation study of the three transiting planets orbiting K2-136, which span the period-radius valley. The K-dwarf host star is relatively young and active, being a member of the Hyades. This presents an opportunity to test different prescriptions of planetary evaporation- as the three planets will have experienced the same X-ray irradiation history. I compare mass-loss histories of the three planets for different atmospheric escape models and conclude that K2-136d must have a mass at the upper end of the range allowed by HARPS-N radial velocity measurements in order to be consistent with mass loss histories of the other planets. I also present an XMM-Newton X-ray observation of K2-136, which show the star to be fainter than suggested by activity relations. This could be the result of either X-ray variability or intrinsically low X-ray levels. The three planets (K2-136 b, c, d) have radii 1.0, 3.0, and 1.5 Earth radii (in order of orbital separation) and all are within 0.15 AU from their host star. Their evaporation pasts, however, reveal that once the three planets were likely sub-Neptunes of size 3 to 3.5 Earth radii and a similar envelope mass fraction of 1.5

Delving further into the radius valley through the characterisation of a sub-Neptune

Larissa Palethorpe[1]
[1] University of Edinburgh

The current trend of the radius valley is that the planets with radii above 2 Earth Radii retain a substantial volatile envelope/atmosphere (sub-Neptunes), while planets below with radii $\sim$ 1.5 Earth Radii are rocky (super-Earths). The origin of the radius gap is still highly debated, and the characterisation of both sub-Neptune and super Earths in this size range will be crucial for ascertaining the truth, helping us to infer the true number of Earth analogues. We report the properties of a sub-Neptune with a 6.5 day orbit, discovered by the TESS mission. We acquired high-precision radial velocity measurements from HARPS-N, along with photometric data from the two separate TESS observations, and a separate set of photometric data from the one observation of a transit with CHEOPS, to confirm the planet detection and determine its planetary properties. We present newly-constrained radius and mass measurements for the systems found through a GP fit with the data, and find that the planet has a moderately eccentric orbit corresponding to a 7 sigma mass and 33 sigma radius detection. These parameters are extremely promising for both characterisation of its internal composition and atmospheric composition due to their degree of accuracy. The resulting planet presents as a sub-Neptune falling in the upper limit of the radius valley with current predictions of a 1-2% H/He atmosphere.

Multi-species hydrodynamic escape along the Sub-Neptune/Super-Earth divide

Matthäus Schulik[1]

[1] Imperial College London

Photoevaporative models are an important tool helping to understand the radius distribution of exoplanets. So far, those models have often focussed on the escape of H/He mixtures, neglecting coupled escape with heavier species, or assumed a fixed hierarchy of major and minor species. In this work, we relax those assumptions by using a truly multi-species simulation framework including radiative transport effects of individual species. This machinery is applied to quantify the final hydrogen mass fraction in heavy-element dominated atmospheres and discuss the impact of chemistry on the escape process.

The effect of pre-impact surface conditions on the efficiency of atmospheric loss driven by giant impacts

Simon Lock[1]

[1] University of Bristol

Terrestrial planets are thought to acquire at least a fraction of their inventory of volatile elements during the main stages of accretion. The atmospheres of the planetary embryos that accreted to form the planets we observed today must therefore have survived the giant impacts (collisions between planet-sized bodies) that are likely common during planet formation. In this work we use 1D hydrodynamic simulations to investigate how efficiently the atmospheres and oceans of proto-planets can be removed during giant impacts. In particular- we quantify the effect that pre-impact surface conditions (such as surface temperature, atmospheric pressure, and ocean mass) have on the efficiency of loss of thin atmospheres. We find that the degree of loss is relatively insensitive to the composition and temperature of the atmosphere, but strongly dependent on the relative mass of the ocean and atmosphere. In cases where the ocean is substantially more massive than the atmosphere, a large range of giant impacts could remove a substantial fraction of the pre-impact atmosphere of a planet. To allow our results to be combined with 3D giant impact simulations, we develop a scaling law that relates the surface conditions to the efficiency of atmospheric and ocean loss. Our results show that the final volatile budgets of planets are critically dependent on the thermal and oxidation state of their surfaces during the final stages of accretion. Stochastic differences in the parameters and timing of giant impacts may therefore be responsible for substantial diversity in the atmospheres of terrestrial planets.

A compact system of super-Earths and Neptunes orbiting an active F8 main sequence star

Zachary Ross[1]
[1] The Open University

DMPP searches for stars with anomalously low chromospheric emission, below the basal limit for main sequence stars. Under the assumption that these stars host short period mass losing planets whose ablated material forms a circumstellar gas and dust shroud that suppresses this emission. In this work we apply this technique to a young- active main sequence star in a nearby cluster. The star's chromospheric emission is not below the main sequence basal level but is clearly below the cluster trend. We use a combination of GLS and recursive periodogram searches to identify significant signals in the RV data with and without correlations with the BIS. Stellar activity causes a number of spurious planetary signals. Trailed periodograms were used to discount any spurious signals that are clearly not of planetary origin. We find five planet candidates in a compact system with periods ranging from 1.5 d to 14.3 d and with minimum masses from 5.2 to 22 $M_\oplus$. Some of our candidate planets may be losing mass- leading to the observed depressed stellar chromospheric emission. The period and mass of these planets puts them in the vicinity of the Neptune desert and the radius valley- providing a key opportunity to further study these demographic features.

Lightcurves and Transit Spectroscopy

The transmission spectrum of WASP-17 b from the optical to the near-infrared wavelengths: combining STIS, WFC3 and IRAC datasets

Arianna Saba[1]

[1] University of Warwick

We present the transmission spectrum of the inflated hot-Jupiter WASP-17 b, observed with the STIS and WFC3 instruments aboard the Hubble Space Telescope, allowing for a continuous wavelength coverage from ∼0.4 to ∼1.7 um. Observations taken with IRAC channel 1 and 2 on the Spitzer Space Telescope are also included, adding photometric measurements at 3.6 and 4.5 um. HST spectral data was analysed with Iraclis, a pipeline specialised in the reduction of STIS and WFC3 transit and eclipse observations. Spitzer photometric observations were reduced with the TLCD-LSTM method, utilising recurrent neural networks. The outcome of our reduction produces incompatible results between STIS visit 1 and visit 2, which leads us to consider two scenarios for G430L. Additionally, by modelling the WFC3 data alone, we can extract atmospheric information without having to deal with the contrasting STIS datasets. We run separate retrievals on the three spectral scenarios with the aid of TauREx 3, a fully Bayesian retrieval framework. We find that, independently of the data considered, the exoplanet atmosphere displays strong water signatures and potentially, the presence of aluminium oxide (AlO) and titanium hydride (TiH). A retrieval that includes an extreme photospheric activity of the host star is the preferred model, but we recognise that such a scenario is unlikely for an F6-type star. Due to the incompleteness of all STIS spectral lightcurves, only further observations with this instrument would allow us to properly constrain the atmospheric limb of WASP-17 b, before JWST or Ariel will come online.

Revisiting a Classic: A Comprehensive Reanalysis of the Transmission Spectrum of the Archetypal Hot Jupiter WASP-17b

Lili Alderson[1]

[1] University of Bristol

WASP-17b is an archetypal hot Jupiter, marked by its frequent inclusion in theoretical and atmospheric retrieval studies, and in JWST Cycle 1 observations. Its inflated radius and long transit make it one of the very best targets for atmospheric characterisation, and as such, transmission spectroscopy of the planet has been performed both from the ground and with space-based telescopes. However, the existing space-based observations, upon which many of these studies critically rely, occurred before many of the now widely used high precision observing modes and analysis techniques were developed. In this

poster- I will present analysis of new high precision WFC3 IR observations, along with a consistent reanalysis of the Hubble and Spitzer data previously presented in Sing et al. 2016. Our updated 0.3-5 micron transmission spectrum achieves a markedly improved average precision of 272 ppm, taking advantage of recent significant advances in exoplanet data reduction and analysis techniques. I will also discuss our comprehensive atmospheric retrieval analysis of the transmission spectrum, through which we detect H2O absorption at ¿7 sigma, and find evidence of CO2 absorption at ¿3 sigma. These retrievals also uncovered complexities that highlight both the importance of using robust statistics for model selection and the need for high precision panchromatic observations, as we transition to a new era of atmospheric characterisation with JWST.

Expected Capabilities of JWST for sub-Neptune Atmospheric Characterizations

Linus Heinke[1]

[1] KU Leuven, University of Edinburgh

The last decade has marked the beginning of a new phase of exoplanet science, the follow-up characterizations of exoplanet atmospheres. Most of the exoplanets that have been spectroscopically characterized so far belong to the subclass of hot-Jupiters. Similarly to what happened for detection, this bias will be gradually alleviated by more capable telescopes and instruments. The advent of the James Webb Space Telescope (JWST), with its greatly increased wavelength coverage and sensitivity- makes it possible to study smaller exoplanets on a much larger scale. Even with JWST, obtaining transit spectra of terrestrial exoplanets will still remain very difficult. The same is not necessarily true for sub-Neptunes, the class of exoplanets that cover the intermediate mass-radius space between gas giants and terrestrial planets. To be able to select optimal sub-Neptune targets for future JWST observations, it is important to know what we can expect to be able to retrieve from JWST transit spectra. To try to answer this question, we have conducted a theoretical study that explores a range of input parameter values that cover the sub-Neptune parameter space. The atmospheric modelling and retrieval framework ARCiS and the noise simulator PandExo were used to turn these parameters into a grid of simulated spectra. The large number of spectra makes full Bayesian retrievals unfeasible, so we instead used a CNN-based machine learning algorithm. By comparing input and retrieved parameters, we can quantify the capabilities and limitations that we can expect JWST to have.

Constraining the presence of water and clouds on WASP-166 b: a bloated planet in the Neptune desert

Marina Lafarga Magro[1]

[1] University of Warwick

With high-resolution spectroscopy we can study exoplanet atmospheres and learn about their chemical composition, temperature profiles, and presence of clouds and winds, mainly in hot, giant planets. State-of-the-art instrumentation is pushing these studies towards smaller exoplanets. Of special interest are the few planets in the "Neptune desert", a lack of Neptune-size planets in close orbits around their hosts. Studying them can provide insight to planetary formation and evolution, and shed light on the origin of the desert. Here, we assess the presence of water in one of such planets, the bloated super-Neptune WASP-166 b, which orbits an F9-type star in a short orbit of 5.4 days. Despite its close-in orbit, it preserved its atmosphere, making it a benchmark target for exoplanet atmosphere studies in the desert. We analyse two transits observed in the visible with ESPRESSO. We clean the spectra from tellurics with an improved version of a principal component analysis, resulting in a significantly better telluric removal- crucial in water searches. We use a Bayesian retrieval tool based on the cross-correlation method to simultaneously estimate limits on the abundance of water and the altitude of a cloud layer, which points towards a low water abundance and/or high clouds. Finally, we perform injection tests which reveal that, if present, a water signal would have been detected with high significance. This is only possible in the visible due to the capabilities of ESPRESSO and the collecting power of the VLT. This work provides further insight on the Neptune desert planet WASP-166 b, which will be observed with JWST.

Variability in Exoplanet Atmospheres

Niall Owens[1]

[1] Queen's University Belfast

Observations of exoplanet systems have revealed the presence of large-scale winds in the atmospheres of exoplanets- through the measurement of offsets of the bright spot in phase-curves and velocity signatures in high-resolution transmission spectra. What is more, for some planets the location of the peak of the phase-curve has been found to vary with time- indicating the presence of e.g., storms. Ground-based observations of secondary eclipses of the ultra-hot Jupiter WASP-12b have been found to be differ significantly, and, if real, would indicate temperature changes in the day-side of this planet of over 300K. We present the phase-curve of WASP-12b at red optical wavelengths obtained from data from the TESS mission at the beginning of 2020 and at the end of 2021. Our preliminary results show no significant variability over the $\sim$ 81 days of TESS observations. Furthermore the observations have revealed the peak of the phase-curve to be offset towards the evening terminator. In addition to the TESS observations, we will also present preliminary results from a ground-based campaign across multiple observatories to investigate the observed variability of the eclipse depth of WASP-12b over different time-scales.

Optimised temporal binning of measured comparison stars for differential photometry

Kathryn Hartley[1]

[1] Durham University

Ground-based high precision observations of the light curves of objects such as transiting exoplanets rely heavily on the application of differential photometry. The flux of the target object is measured relative to a comparison star in the same field, allowing correction for systematic trends in the light curve, mainly due to atmospheric effects including the variation of extinction with airmass. However, the precision of the light curve is then limited by the random noise for the measurements of both the target object and the comparison star. For time-resolved photometry using short exposure times of up to a few tens of seconds- in many cases the time scale of the systematic variations due to atmospheric (or other) effects may be much longer than the cadence of the observations. In this case the overall signal-to-noise ratio of the observation may be improved significantly by applying some temporal binning to the measurements of the comparison star- before comparison with the target object- without reducing the cadence of the overall light curve. We will describe a data reduction pipeline for implementing this method which optimises the number of frames to be binned for the comparison star- and we will present some example results for time-resolved photometric data.

Planet Formation

The influence of binarity on disc fragmentation

Ken Rice[1]

[1] University of Edinburgh

There are indications that systems hosting close-in massive planetary-mass and brown dwarf companions have a higher binarity than that of field stars. We use SPH simulations to explore if this could be partly explained by the binary companions triggering disc fragmentation when these systems were very young and the disc was still relatively massive.

Planet formation in massive stellar clusters

Lin Qiao[1]

[1] Queen Mary University of London

There has been increasing acknowledgement that most stars (and their protoplanetary discs) form in massive stellar clusters. The UV radiation field emitted by the massive stars in such clusters can affect protoplanetary discs via external photoevaporation- where UV radiation heats and disperses material from disc surfaces. Past planet formation and evolution models generally use either extended long-lived discs neglecting external photoevaporation- or include some prescription of external photoevaporation that is tuned to produce disc lifetimes consistent with observations. However- realistically the interplay between the ongoing star formation and disc evolution/planet formation in a dynamically evolving cluster is much more complicated. Stars form at different times and locations in clusters- with some stars being initially embedded in star forming clouds that later disperse. This means discs around stars in a cluster experience time varying radiation fields- with some discs being initially shielded from strong radiation for various periods. Recently I performed the first calculations modelling disc evolution in a stellar cluster formation and feedback simulation model (Qiao et al. 2022). I will discuss the impacts of the time varying UV radiation and shielding of the clouds on disc evolution, and new work in which we investigate the impacts on planet formation simulated with n-body models based on Coleman & Nelson (2014) code. The goal is to eventually determine how, when and where a star forms in a cluster impacts planetary architectures (Qiao et al. in prep.).

Prograde spinup during gravitational collapse

Marc Brouwers[1]

[1] University of Cambridge

Many objects that form via a gravitational collapse or contraction appear to rotate around their own axis (spin) in a manner that aligns with their orbit around larger parent structures. Systematic prograde rotation is found in the planets and larger asteroids of the Solar System, in the stars of several open clusters, as well as in the molecular clouds of different galaxies. Remarkably, the fact that such a spin-orbit alignment exists across different scales has received little scientific attention in the last decades, while a satisfactory answer remains to be found. We present a new mechanism that describes how collections of particles or 'clouds' gain a prograde rotational component when they collapse or contract while subject to an external- central force. The effect is geometric in origin, as relative shear on curved orbits moves their shared center-of-mass slightly inward and toward the external potential during a collapse- exchanging orbital angular momentum into aligned (prograde) rotation. We highlight an application to the Solar System, where we suggest that prograde spin-up can explain the frequency of binary comets in the Kuiper belt with prograde rotation.

N-body simulations of planet formation via pebble accretion

Soko Matsumura[1]

[1] University of Dundee

The connection between initial disc conditions and final orbital and physical properties of planets is not well-understood. We numerically study the formation of planetary systems via pebble accretion in an actively accreting, nearly inviscid disk. Our simulations reproduce the overall distribution trends of semi-major axes, eccentricities, planetary masses, and occurrence rates of giant planets very well. We will discuss the effects of disc properties such as masses, dissipation timescales, and metallicities on planet formation outcomes.

Planetesimal Belts in Wide Binaries: A Kozai Origin for Boyajian's Star?

Steven Young[1]

[1] University of Cambridge

Planetary systems have been found to be a common occurrence across the galaxy and consist of both planets and/or belts of planetesimals. The orbits of planetesimals in these belts can be perturbed by the presence of nearby massive bodies such as a distant companion star. These companions, if sufficiently inclined and eccentric- can excite planetesimals to extremely high eccentricities: an effect known as the 'Eccentric Kozai Mechanism'. These planetesimals can then pass very close to their host star- possibly producing observable transits. This is one explanation for the deep- aperiodic dips in the light curve of Boyajian's star which has recently been confirmed to have a wide binary companion. I will present a Monte Carlo model of the Kepler field to investigate how often this mechanism would be expected to produce such a signature and hence how important distant stellar companions are to the evolution of planetary systems.

Planet formation in MHD wind-driven disks via pebble accretion

Yunpeng Zhao[1]

[1] University of Dundee

Pebble accretion, a much faster planetary accretion mechanism than the classical planetesimal accretion was proposed to explain the formation of a large diversity of planetary systems (Lambrechts & Johansen 2012). Over the past decade, many in-depth models have been established to construct the emerging paradigm of pebble accretion (e.g. Ida et al. 2016; Johansen & Lambrechts 2017). Herewithin, most of works are based either on the classic alpha disk (Shakura & Sunyaev 1973), or the "two-alpha" disk model that mimics the effects of the MHD wind-driven accretion by using one alpha for disk accretion and the other for local disk evolution (e.g. Bitsch, Izidoro, & Johansen et al. 2019, Matsumura, Brasser, & Ida 2021). However, these models do not properly take account of the MHD wind-driven disk evolution. Motivated by the recent MHD wind-driven disk model (Tabone et al. 2021), this work investigates how formation and orbital distributions of planets are affected by disk evolution, in particular by the balance between disk turbulence and MHD disk winds.

Exoplanet eccentricity excitation via mean-motion resonances and photoevaporation

Katie Lim[1]

[1] Imperial College London

The high eccentricities of extrasolar giant planets are an unsolved problem. In multi-planet systems, orbital eccentricities can be excited via capture into mean-motion resonances during planetary migration. However, interactions between a planet and its parent disk tend to damp out eccentricities, limiting its growth. We hypothesise that removing gas from the disk by photoevaporation provides a pathway for planets to reach higher eccentricities. This pathway works as smaller gas surface densities weaken the eccentricity damping. We investigate whether the combination of mean-motion resonances and photoevaporation can reproduce the observed eccentricities of extrasolar giant planets through numerical simulations. We run 2D FARGO simulations of two planets of mass 1 – 10 M_{Jup} that are captured into a mean-motion resonance. We compare their eccentricity evolution over $\sim$1 Myr in disks with and without photoevaporation. Our results show that photoevaporation can significantly influence eccentricity evolution over the disc's lifetime. Thus, we believe it is necessary to consider disk photoevaporation when discussing the orbital evolution of planets.

Retrievals

Exploring the Atmospheres of Exo-Venuses with JWST

Agnibha Banerjee[1]
[1] The Open University

With the James Webb Space Telescope, we will soon be able to obtain transmission spectra of terrestrial planets- which has only been possible for gas giants so far. This group of rocky planets would possibly also contain hot and cloudy planets similar to Venus, whose atmospheres might be dominated by a spectrally active gas like CO2, instead of H2 and He as is the case for gas giants. I will present the modifications required in the current retrieval methods to simulate such atmospheres using NEMESIS. The prior used for the dominant gas needs to be heavily skewed, or priors such as Centred log-ratio need to be used. Also, some factors that have a negligible impact on the spectra when gases are present in trace amounts, like the isotopologue abundance ratio, will need to be taken into consideration. The current models of clouds on Venus indicate the presence of multiple particle sizes and variations with altitude. Such complex models are hard to implement for retrievals and are also computationally expensive. I will discuss whether simpler parametric clouds can be used to retrieve atmospheric properties from data simulated using the complex cloud models.

Atmospheric Retrieval of Rocky Exoplanets in Thermal Emission

Anjali Piette[1]
[1] Carnegie Earth & Planets Laboratory

Understanding the presence and nature of rocky exoplanet atmospheres is critical to understanding this diverse population of exoplanets and its potential for habitability. In particular, emission spectroscopy with JWST is a promising technique to determine the presence of and characterise atmospheres of rocky exoplanets, probing both their chemistry and thermal profiles. Comprehensive retrieval approaches are required to interpret such observations within a robust statistical framework. In this talk, I will present HyDRo: an atmospheric retrieval framework for thermal emission spectra of rocky exoplanets. HyDRo does not make prior assumptions about the background atmospheric composition, and can therefore be used to interpret spectra of secondary atmospheres with unknown compositions. I will show how HyDRo can be used to assess the chemical constraints which can be placed on rocky exoplanet atmospheres using JWST. I identify the best currently-known rocky exoplanet candidates for spectroscopic observations in thermal emission with JWST, finding >30 known planets whose thermal emission will be detectable by JWST/MIRI in fewer than 10 eclipses at R $\sim$ 10. I then consider the observations required to characterise the atmospheres of three promising rocky exoplanets across the $\sim$ 400-800K equilibrium temperature range: Trappist-1b, GJ1132b, and

LHS3844b. Considering a range of CO_2, to H_2O-rich atmospheric compositions, I find that CO_2 and H_2O can be detected in these atmospheres with reasonable amounts of JWST observing time, and that their abundances can be constrained with good precision. HyDRo will allow important atmospheric constraints on rocky exoplanets with JWST observations, providing crucial insights into their geochemical environments.

Retrieval of Hot Jupiter Phase Curves

Jingxuan Yang[1]
[1] University of Oxford

Spectroscopic emission observations of tidally locked gas giants at multiple orbital phases inform us about the three-dimensional structures of their atmospheres, in particular their thermal structure and chemical abundances. In order to extract information from these observations, we have developed a retrieval framework which fits all phases of such 'phase curve' observations simultaneously. Our forward model contains a three-dimensional parametric temperature map and a free chemistry model, and we developed a Python version of the Nemesis radiative transfer code to simulate phase curves from temperature maps and chemistry model. We use the MultiNest algorithm to explore the parameter space of our forward model and place constraints on chemical abundances. We tested our retrieval scheme on HST/WFC3 and Spitzer/IRAC observations of WASP-43b, as well as simulated phase curves from GCM models.

To Sample or Not To Sample: Retrieving Exoplanetary Spectra with Variational Inference and Normalising Flows

Kai Hou Yip[1]
[1] University College London

Current endeavours in exoplanet characterisation rely on atmospheric retrieval to quantify crucial physical properties of remote exoplanets from observations. However, the scalability and efficiency of the technique are under strain with increasing spectroscopic resolution and forward model complexity. The situation becomes more acute with the recent launch of the James Webb Space Telescope and other upcoming missions. Recent advances in Machine Learning provide optimisation-based Variational Inference as an alternative approach to perform approximate Bayesian Posterior Inference. In this investigation we combined Normalising Flow-based neural network with our newly developed differentiable forward model, Diff-Tau, to perform Bayesian Inference in the context of atmospheric retrieval. Using examples from real and simulated spectroscopic data, we demonstrated the superiority of our proposed framework: 1) Training Our neural network only requires a single observation; 2) It produces high-fidelity posterior distributions similar to sampling-based retrieval and; 3) It requires 75% less forward model computation to converge. 4.) We performed, for the first time, Bayesian model selection on our trained neural network. Our proposed framework contribute towards the latest development of a neural-powered atmospheric retrieval. Its flexibility and speed hold the potential to complement sampling-based approaches in large and complex data sets in the future.

Retrieving multi-dimensional winds from eclipse map observations of temperature

Mark Hammond[1]
[1] University of Oxford

The winds in the atmospheres of exoplanets affect observations, chemical composition, and cloud coverage. The novel patterns they form are also of intrinsic theoretical interest. So far, it has only been possible to measure these winds indirectly using high-resolution spectroscopy, which produces large-scale wind speed estimates at low pressures. I will present a new method to retrieve spatially resolved wind velocities at photospheric pressures. This retrieval method uses multi-dimensional observations of temperature, such as those soon to be available from eclipse maps measured by JWST. We use a well-known method from studies of the Earth's atmosphere to express the fluid equations in terms of a balance between winds and height (or temperature). We then invert this equation to express winds as a function of height which is solvable given observational data. I will show that with perfect three-dimensional input data, this method gives a very accurate retrieval of three-dimensional wind patterns on hot Jupiters, especially their equatorial jet. With imperfect simulated observational data the results are still reasonably accurate. We suggest that this method can be used accurately with JWST observations, and that the resulting wind retrievals can be used to constrain atmospheric models.

A Combined High, and Low-Resolution Retrieval of a Hot Jupiter using IGRINS/Gemini South and WFC3/HST

Peter Smith[1]
[1] Arizona State University

High resolution cross-correlation spectroscopy (HRCCS) is an emerging method for characterizing exoplanets from the ground. It utilizes the planet signal's time-resolved Doppler shift to disentangle it from the dominant telluric and stellar features. High spectral resolution combined with wide wavelength coverage allows for precise constraints on molecular abundances and thermal structure with novel atmospheric retrieval techniques. High resolution data can be combined with low resolution space-based data in retrieval, probing a wide range of altitudes and incorporating continuum information otherwise lost through detrending methods common in HRCCS. We present retrieval results of combined observations of a benchmark hot Jupiter WASP-77 Ab with both the IGRINS instrument on Gemini South (R $\sim$ 45,000) and WFC3 on the Hubble Space Telescope (R $\sim$ 100). We report a superstellar C/O ratio and a substellar metallicity, indicative of diverse formation pathways for hot Jupiters. We also report a bounded constraint on the carbon-12 to carbon-13 isotope ratio, the first such measurement for a transiting exoplanet.

Stellar Parameters and Activity

On the Hunt for Earth-analogues: Mitigating the impact of stellar activity on low-mass exoplanet discovery

David Jackson[1]

[1] Queen's University Belfast

An exciting era in exoplanet research is emerging where advances in technology will make it possible to discover Earth-analogue planets for the first time. These advances include the next generation of extreme precision radial velocity spectrographs (such as ESPRESSO), space-based transiting planet discovery missions (e.g. PLATO), as well as the most intensive radial velocity searches ever undertaken (e.g. the Terra Hunting Experiment). Despite such advances, stellar activity represents the limiting factor in our ability to detect Earth-analogues. In this poster I will review the main stellar activity culprits that act as a barrier to reaching the sensitivities in the radial velocity measurements used to confirm exoplanets. I will also present new stellar activity indicators found by the group at QUB that tracks plage regions (thought to be the major barrier to Terra Hunting capabilities). I will demonstrate how these new activity proxies can be used to mitigate the impact of stellar activity in comparison with more 'conventionally' used indicators (such as log R'HK), as well as their potential to constrain the stellar geometry.

The revised Vasy indicator: characterising stellar variability for exoplanet detection through line profile asymmetries

Laura Millson[1]

[1] University of Warwick

The interaction between a star's magnetic field and the convection currents within its interior generate various phenomena on the stellar surface, such as granulation, oscillations, starspots and faculae. These produce stellar variability in radial velocity measurements, which is one of the greatest barriers in the detection of exoplanets, as, for example, variability can easily swamp the small Doppler shifts induced by an Earth-sized planet. As stellar variability introduces asymmetries into the shape of the stellar absorption line profiles used to measure radial velocities, line shape indicators can be used to characterise these asymmetries. We present a revision of one such stellar indicator, the velocity asymmetry (Vasy) indicator. Vasy, which was first introduced by Figueira et al. (2013), evaluates the radial velocity information of the line profile by comparing the red wing against the blue wing. It was later amended in Figueira et al. (2015), as it was found to alter with changes in radial velocity (such as those induced by the presence of a planet), making it not possible to disentangle the real motion of the star from its variability. A modification of Vasy was also later proposed by Lanza et al. (2018). Here we present

our updated Vasy indicator, and test it against new HARPS-N solar data. This revised indicator could provide the means to characterise stellar variability and disentangle it from potential planetary signals.

Optimal parameter space for detecting stellar differential rotation and centre-to-limb convective variations

Nicolas Roguet-Kern[1]

[1] University of Fribourg, University of Warwick

To take full advantage of the improved precision of recent instruments (e.g. ESPRESSO), a more detailed understanding of the stellar surface is important. In this talk I will present the results of our work on exploring the parameters space to detect differential rotation (DR) and centre-to-limb convective variations (CLV), using the reloaded Rossiter-McLaughlin method. This technique allows us to probe variations in the stellar surface by resolving spectra from the regions that are occulted by a planet as it transits. We simulated a typical transiting hot Jupiter (similar to HD 189733) in a star-planet system with and without convective effects to map the optimal regions of the parameter space for retrieving the injected differential rotation. We also explored all possible ranges of projected obliquity (spin-orbit angle), stellar inclination, and impact parameter, as well as differences in instrumental configuration, stellar magnitude, and exposure time. Throughout this talk, I will show that DR is more easily retrieved at low-impact parameters and share our findings on the parameter space limitations of a HARPS-like setup as compared to an ESPRESSO like set up. Finally, I will demonstrate how in certain instances CLV and DR effects may be confused at first glance, but later distinguished by examining the retrieved physical parameters.

Characterising the Effects of Active Host Stars on Exoplanet Transmission Spectra

Alex Thompson[1]

[1] University College London

For an exoplanet transit, the planet and its host star are observed as an unresolved source. This intrinsic entanglement of stellar and planetary signals means that it is essential we investigate and correct for any stellar contamination present. Such contamination is introduced by active regions on the stellar photosphere in the form of colder spots and hotter faculae, both of which may cause the transit chord (the true light source) to deviate from the pre-transit disk integrated stellar spectrum. Correction for stellar activity is essential, particularly at the shorter optical / near UV wavelengths probed by exoplanet characterisation missions, as its effects are strongest in this region and can mask or mimic genuine absorption features originating from the exoplanet atmosphere. The extent of the contamination is also expected to vary strongly as a function of spectral type, substantially increasing for earlier type K and M dwarfs. I present a correction method for this contamination utilising the TauREx3 retrieval code and a specialised stellar activity

plugin (TauREx Lightsource) which introduces four new fittable parameters related to the heterogeneity of the host star. TauREx lightsource is then demonstrated for both simulated and real observations to quantify how important the correction will be for both existing and future instruments.

Stellar Parameters for the Planetary Mass-Radius diagram

Angharad Weeks[1]
[1] University College London

Understanding the diversity and architecture of the systems of the over 5000 discovered exoplanets, is imperative to improve our understanding of the planets themselves. To do so, the system host star, must be characterised. A broad range of methods exist for such analysis, including those based on, spectroscopy, photometry, astrometry, asteroseismology and interferometry. However, the expanding catalogue of exoplanetary systems lacks a formal, homogeneous approach for host star, characterisation. Using data from Gaia Data Release 3, we homogenise the characterisation of fundamental host star, parameters including mass, radius, age, and heliocentric distance. This is done by applying the Bayesian Stellar Algorithm (BASTA, Aguirre Borsen-Koch et al. 2022, MNRAS, 509, 3) which uses astrophysical observables and BaSTi stellar evolution models (BaSTi, Pietrinferni et al. 2021, APJ, 908, 1), to determine stellar properties. I will present a sample of homogenously characterised stars, hosting small planets which have been studied by both the radial velocity and the transit method. From these homogenous stellar parameters, I will discuss how we can re-calculate the planetary parameters and begin to disentangle the planetary mass-radius diagram. Additionally, I will demonstrate that stars in an asteroseismic sub-sample, those with information available from asteroseismic analysis from Kepler, and TESS observations, can be treated as a benchmark for comparison and validation of our method.

Gaussian Processes and physical stellar properties

Belinda Nicholson[1]
[1] University of Oxford

Gaussian Process (GP) regression has become an increasing popular data analysis tool in stellar and exoplanet astronomy, yet questions remain as to the extent to which GP hyper-parameters relate to physical stellar properties. This seminar shows the results of tests of GP regression with the quasi periodic (QP) and QP cosine kernels on a simulated stellar light curves and radial velocity times series, with the aim of determining the correlation, if any, between physical properties of a star, and the recovered GP hyper-parameters. This seminar also explores the differences in the recovered QP GP hyper-parameters between light curve data and 'perfectly' sampled radial velocity data, as well as examining the effects of degrading radial velocity time sampling and signal-to-noise on recovering the same GP hyper-parameters.

Gaussian Process for planetary detection

Federica Rescigno[1]

[1] University of Exeter

Breaking the stellar activity radial velocity barrier is vital for the detection and characterisation of exoplanets, in particular small Earth-like planets. A planetary rv signal can be easily drowned or mimicked by rv variations generated by activity on the surface of the host star. Gaussian Process Regression, paired with Markov Chain Monte Carlo parameter space exploration, is a powerful tool for modelling these stellar-induced signals to be subtracted from the raw data, and for searching the Keplerian model that best fits the reduced data at the same time. I present an in-process GP Regression and MCMC optimisation pipeline for exoplanetary RV detangling. I will also use this pipeline to further analyse the behaviour of the polarised magnetic flux, as a stellar activity proxy, and to compare their quasi-period behaviour to those of planet-subtracted stellar RVs.

TESS

Young planets are key: HIP 67522 b and TOI 4562 b

Alexis Heitzmann[1]
[1] QMUL

A wealth of models to explain the early evolution of planetary systems have emerged following the discovery of nearly 5000 unexpectedly diverse exoplanets. Validating these theories requires knowledge of planetary properties at all stages of a system's life and is best informed by giant planets, more accessible to current detections methods and excellent tracers of formation history. Currently, the early days (¡ 500 Myr) of planets orbiting Sun-like stars is greatly under sampled and it is essential to increase the pool of young giant planets. Here, we present HIP 67522 b and TOI 4562 b, two young giant planets discovered by the TESS mission, that contribute to our understanding of early planet evolution. HIP 67522 b is a 17 Myr old Jupiter sized planet for which our obliquity measurement shows a well-aligned orbit and TOI 4562 b is a 200 Myr old, long period and highly eccentric Jupiter like planet that probably has an outer companion.

Identifying transiting Neptunes and sub-Neptunes in the NGTS survey through cross-correlating with TESS TOIs

Alicia Kendall[1]
[1] University of Leicester

Through cross-correlating TESS TOIs with NGTS survey fields, we noticed that some TOIs are not always independently discovered by NGTS. This is often due to shallow transit depth, close to the signal-to-noise limit of NGTS (1mmag), and/or because of limited in-transit NGTS data, resulting in the BLS algorithm being unable to identify the correct orbital period. To rectify this, we use the TOI period to phase-fold the NGTS data and draw out the transits that have been missed. By combining TESS and NGTS data, alongside other photometric follow up, the baseline of observations is greatly extended and the total number of observed transits is increased. This leads to improved ephemerides, and potentially improves estimates of the planetary radii and other parameters. The longer baseline also allows to better determine stellar rotation periods, or even search for additional planets in the systems. A key benefit of this approach is the identification of previously missed Neptune and sub-Neptune sized planet candidates in NGTS data.

Automated Vetting and Validation of TESS Exoplanet Candidates

Andreas Hadjigeorghiou[1]
[1] University of Warwick

Presenting RAVEN (RAnking and Validation of ExoplaNets), an automated vetting and validation pipeline for TESS exoplanet candidates. The pipeline uses Machine Learning (ML) algorithms to separate planetary candidates from False Positives (FP). The ML models are trained on a synthetic training set of TESS lightcurves,where simulated transits of planets and astrophysical FPs have been injected. The ML classification score is then combined with pre-computed prior probabilities for the planet and all FP scenarios to calculate their posterior probability. Candidates with a probability greater than 99% to be a planet are statistically validated. With posterior probabilities calculated for all candidates, our results can also be used to rank and prioritise candidates for valuable follow-up observations and even inform planetary occurrence calculations. The pipeline will be applied on lightcurves extracted from the Full Frame Images- for stars down to magnitude 13.5, allowing us to simultaneously find and validate planets out of about 13M stars. For this talk, the results of applying the pipeline to all current TOIs will be presented- providing the first insight into its performance.

An Automated Search for Transiting Exocomets with TESS

Azib Norazman[1]
[1] University of Warwick

The term exocomets refers to analogues of our Solar System comets. They are small icy planetesimal bodies that orbit stars other than the Sun and are thought to be the remnants of exoplanet formation. In recent years, there have been a small number of stars that have unique asymmetric dips in their transits from photometric data that cannot be caused by a planet transit. The most prominent example of this so far are from the lightcurves of Beta Pictoris, a young A-type star. Recent literature has also indicated that exocomet detections are more likely in younger, A/F-type stars. As the TESS mission carries out an all-sky survey, there is now the opportunity to explore this hypothesis further and explore the detection rates of exocomets with relation to the spectral type of their host star- uncovering the occurrence rates as a function of spectral type and stellar age. A simple automated method to detect exocomet transits was developed for the Kepler mission. As TESS expands the sample of stars over the whole sky, a plethora of star systems will be explored. However, the nature of the all-sky search results in a wide range of astrophysical variability in addition to the different systematics the spacecraft has compared to Kepler. Therefore, development of the search method for TESS is essential. For my poster, I will present the automated search algorithm used to find potential asymmetric transit dips in TESS, and the results of my search at the time of the conference

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NOI-103322/TOI-4339: A newly discovered brown dwarf in the desert from NGTS and TESS

Beth Henderson[1]

[1] University of Leicester

We have discovered a brown dwarf which is orbiting a 0.57 MSun- 0.57 RSun M0/M1 dwarf. We first identified the brown dwarf within the Next Generation Transit Survey, with supporting observations found in TESS sectors 11 (30 minute) and 38 (2 and 30 minute). We confirmed the discovery with follow-up photometry from the South African Astronomical Observatory and RV measurements from HARPS, which allowed us to characterise the system. We find a period of around 1.254 days, a mass close to the Hydrogen burning limit and radius of 0.8 RJup. We estimate the age of the system to be around 5-10 Gyrs, using model isochrones. We have found this to be in agreement with SED fitting and statistical modelling of the primary and common proper motion companion star spectra, making it an old, compact brown dwarf. The short period puts it within the brown dwarf desert, making it another important discovery within this scarcely populated region.

A dedicated search for nearby young transiting planets with TESS

Edward Gillen[1]

[1] Queen Mary University of London

Stars in young associations, open clusters and co-moving groups can be precisely dated, which make them promising targets for exoplanet searches seeking to probe the early evolution of planetary systems. Detecting young transiting planets has been historically difficult. However, because young stars display significant variability, which masks the planetary transits. Our new search algorithm, Wiggle, simultaneously models the stellar variability using Gaussian process regression as it searches for transits- which increases its sensitivity to shallow signals. I will present the first results from a dedicated search for young planets in TESS 2-min data, which include a likely young planetary system comprised of two sub-Neptunes, a handful of promising new candidates, the recovery of many TOIs, and the serendipitous detection of new complex rotators and eclipsing binaries. Finally, I will conclude with an outlook towards future prospects for the search and our understanding of young planetary systems with TESS.

The YOUNGSTER Program

Matthew Battley[1]
[1] University of Warwick

Although over 5000 validated exoplanets are currently known, there are still large gaps in the community's understanding of how planets form and evolve. Young exoplanets (<1Gyr) hold the key to answering some of these outstanding questions, existing in one of the most interesting eras of exoplanet evolution, where their orbital locations, compositions and atmospheres are rapidly evolving. However, such young exoplanets are much more difficult to detect than their older counterparts due to the inherently increased stellar variability/activity of their young host stars. The signals of this variability are diverse and challenging, often with periods similar to (or faster than) planetary periods but with amplitudes much larger than the signals of even Jupiter-sized planets. This has seriously challenged traditional 'one size fits most' exoplanet detrend and search algorithms. In order to find new, smaller exoplanets around young stars, it is imperative to understand the stellar variability of their hosts. This poster will present the beginning of the YOUNGSTER program, or "YOUNG Star detrending for Transiting Exoplanet Recovery", which aims to classify young stellar variability alongside planetary searches and use these classifications to inform targeted detrending methods. In particular, this poster will focus on the first step in this process: using Kohonen Self Organising Maps (SOMs) to explore young star variability present in the first year of observations from the Transiting Exoplanet Survey Satellite (TESS), with such knowledge valuable to understand how these may be split into different groups in future searches for young exoplanets. It will also show how pre-training the Self-Organising Map can be beneficial to assigning known variability classes to previously unseen light-curves. The results from this analysis provide a crucial building-block towards more targeted detrending of young star light-curves, and will extend the search for exoplanets to smaller planets around more active hosts.
