Towards Other Earths III: The Planet-Star connection

17-21 July 2023, Porto, Portugal

Abstract book

Oral communications

Topic 1 - Detection - Session 1

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09:15	09:45	00:30	Joao Faria
			Revealing new worlds with precise radial velocities
09:45	10:05	00:20	Shweta Dalal (University of Exeter)
			Predicting convective blueshift and radial-velocity dispersion due to granulation for FGK stars
10:05	10:25	00:20	Andrea Bonfanti (Austrian Academy of Sciences)
			Cleaning RV time series from stellar activity: SN-fit and bp-method

Revealing new worlds with precise radial velocities

Joao Faria

(Instituto de Astrofísica e Ciências do Espaço)

The era of extreme precision radial velocities is here, allowing us to detect and determine the masses of numerous low-mass planets, some resembling Earth.
But stellar activity continues to pose a very big challenge to the radial velocity technique, by masking and sometimes mimicking the signals caused by the planets. Besides exquisite high-precision data from dedicated spectrographs, one needs also advanced analysis techniques in order to separate the stellar and planetary signatures. In this talk, I will discuss recently developed models designed to address stellar activity and some of the interesting planets they allowed to detect.
I will also speculate about the role precise radial velocities may play in the future in-depth characterization of exoplanets.

Predicting convective blueshift and radial-velocity dispersion due to granulation for FGK stars

Shweta Dalal
(University of Exeter)
Co-authors: R. D. Haywood, A. Mortier, W.J. Chaplin and N. Meunier

To detect Earth-mass planets using the Doppler method, a major obstacle is to differentiate the planetary signal from intrinsic stellar variability (e.g., pulsations, granulation, spots and plages). Convective blueshift results from small-scale convection at the surface of Sun-like stars.
Stellar surface convection, or granulation, becomes relevant for Earth-twin detections as it exhibits Doppler noise on the order of 1 m/s.
Here, we present a simple model for convective blueshift based on fundamental equations of stellar structure. Our model successfully matches observations of convective blueshift for FGK stars. Based on our model, we also compute the intrinsic noise floor for stellar granulation in the radial velocity observations. We find that for a given mass range, stars with higher metallicities display lower radial-velocity dispersion due to granulation, in agreement with MHD simulations. We also provide a set of formulae to predict the amplitude of radial-velocity dispersion due to granulation as a function of stellar parameters. Our work is vital in identifying the most amenable stellar targets for EPRV surveys and radial velocity follow-up programmes for TESS, CHEOPS, and the upcoming PLATO mission.

Cleaning RV time series from stellar activity: SN-fit and bp-method

Andrea Bonfanti
(Austrian Academy of Sciences. ÖAW-IWF, Graz, Austria)

The radial velocity (RV) technique is one of the most successful method for detecting exoplanets and it is based on measuring the Doppler reflex motion induced on a star by its orbiting planets. However, the stellar activity in the form of oscillations, granulations, spots or faculae also produces Doppler signals which may completely hide the Keplerian signal of an exoplanet.
Removing the stellar activity contribution from a RV time series is then crucial to hopefully detect an exoplanet. While exoplanets produce a Doppler-shift on the CCF extracted from the stellar spectrum without modifying its shape or its width, active regions produce variations in both the asymmetry and the FWHM of the CCF. During my talk I will present a novel technique for removing stellar activity that can be divided in two steps. In the first step a Skew-Normal (SN) fit is applied to the CCF to retrieve not only the Doppler signal which constitutes the RV time series, but also the FWHM, the contrast, and the skewness of the fitted function. These hyperparameters are activity indicators and they are employed during the second step, when the RV time series is cleaned from stellar activity. To this end, I will present you the breakpoint (bp) method, which belongs to the family of change point detection algorithm. In fact, if on the one hand the Keplerian signal is persistent along the RV time series, on the other hand active regions (hence their RV signal) evolve over time. The core idea of the bp method is to evaluate those locations along a time series where the correlation changes involving the activity indicators are statistically significant. Applying a piecewise detrending rather than an overall correction (oc) turns out to be much more effective in removing the stellar activity contribution as shown by different examples where this framework has been applied.

Topic 1 - Detection - Session 2

Topic 1 - Detection - Session 2			
11:00	11:20	00:20	Ancy Anna John (University of St Andrews): “Pushing through the 1 m/s Radial-Velocity barrier in HARPS-N Rocky Planet Search targets.”
11:20	11:40	00:20	André M. Silva (IA) “Approaches for RV extraction: s-BART and the first steps towards a fully Bayesian model”
11:40	12:00	00:20	Jennifer Burt (JPL) “An Archival Radial Velocity Survey of Targets for NASA's Direct Imaging Flagship”
12:00	12:20	00:20	Angelica Psaridi (Geneva Observatory) “Exploring the densities of planets orbiting hot stars above the Kraft break”
12:20	12:40	00:20	Elisa Delgado Mena (IA) “Long period RV signals in intermediate mass evolved stars: planets, oscillations or stellar activity?”

Pushing through the 1m/s Radial-Velocity barrier in HARPS-N Rocky Planet Search targets.

Ancy Anna John
(University of St Andrews)

In the hunt for Earth twins, which demands a radial-velocity (RV) precision of 10 cm/s, minimizing the impact of stellar variability in RV measurements is a critical challenge. Since 2012, a dedicated programme has been deployed to use the high-resolution echelle spectrograph HARPS-N, mounted on the Telescopio Nazionale Galileo to conduct a blind RV Search for Rocky Planets (RPS) around bright stars in the Northern Hemisphere. Here we describe the results of a comprehensive search for planetary systems in two RPS targets HD 166620 and HD 144579, of which HD 166620 was recently identified as the first unambiguous Maunder minimum analogue. We used a set of wavelength-domain line profile decorrelation vectors to mitigate the stellar activity and performed a deep search for planetary reflex motions using a transdimensional nested sampler. This pipeline, TWEAKS, is designed for attaining a sub-m/s detection threshold at long orbital periods, by combining the wavelength-domain and time-domain stellar activity mitigation.

We found no significant detections in either of the stars. The results were validated by performing data-splitting exercises and testing them with injection and recovery tests. Additionally, we obtained the detection limits on the HARPS-N RVs and found that the likelihood of finding a low-mass planet increases noticeably across a wide period range when the inherent stellar variability is corrected for using SCALPELS U-vectors. The 54 cm/s detection threshold achieved based on the aforementioned decorrelations brings us closer to the theoretical precision value provided by the HARPS-N instrument (50 cm/s). Moreover, we are now able to detect planets with masses $\leq 1 M_{\oplus}$ in stars with comparable activity levels to HD 166620 and HD 144579.

Approaches for RV extraction: s-BART and the first steps towards a fully Bayesian model

André M. Silva
(Instituto de Astrofísica e Ciências do Espaço)

Co-authors: João P. Faria, Nuno C. Santos, Pedro T. P. Viana; Sérgio G. Sousa

The level of precision needed to detect Earth-like planets orbiting other suns requires new development in both instrumentation (e.g. ESPRESSO) and the data analysis paradigm. In recent years we have seen the advent of new RV extraction methodologies that can, under certain conditions, surpass the widely used Cross-Correlation Function (CCF) method. As an example, using a template matching approach, the s-BART pipeline (Silva et al. 2022) has been recently featured in the detection of a candidate short-period planet, with approximately half of Earth's mass, orbiting Proxima Centauri (Faria et al. 2022). This framework assumes an achromatic RV-shift, compatible with what we expect to find from planetary companions, with RVs being computed through the characterization of their posterior probability.

However, in s-BART, the usage of a stellar model built from observations of the star leads to a mixture of information between the model (the stellar template) and the data with which the model is compared to (the observations). Even though this is not fully compatible with a Bayesian framework s-BART ignores this problem, since the information of a single observation is much smaller than the one from the template. To overcome this first-order approximation, the next step is to move towards a fully probabilistic stellar model where the RV extraction and telluric correction occurs simultaneously. In this talk we present the s-BART method, highlighting some of its recent results on different spectrographs. Afterwards, we present preliminary results of a new methodology that leverages Gaussian Processes to generate a model of the stellar spectra of each order, whilst enforcing the assumption of an achromatic RV-shift, compatible with what we expect to find from planetary companions.

An Archival Radial Velocity Survey of Targets for NASA's Direct Imaging Flagship

Jennifer Burt
(JPL)

Co-authors: Katherine Laliotis, Eric E. Mamajek, Zhexing Li, Volker Perdelwitz, Jinglin Zhao, R. Paul Butler, Bradford Holden, Lee Rosenthal, B. J. Fulton, Fabo Feng, Stephen R. Kane, Jeremy Bailey, Brad Carter, Jeffrey D. Crane, Elise Furlan, Crystal L. Gnilka, Steve B. Howell, Gregory Laughlin, Stephen A. Shectman, Johanna K. Teske, C. G. Tinney, Steven S. Vogt, Sharon Xuesong Wang, and Robert A. Wittenmyer

Directly imaging temperate rocky planets orbiting nearby, Sun-like stars with a space telescope is a high priority goal of the Astro2020 Decadal Survey. To prepare for future direct imaging surveys, the list of potential targets should be thoroughly vetted to maximize efficiency and scientific yield. We present an analysis of archival radial velocity data for southern stars from the NASA/NSF Extreme Precision Radial Velocity Working Group's list of high priority target stars for future direct imaging missions (drawn from the HabEx, LUVOIR, and Starshade Rendezvous studies). For each star, we have constrain the region of companion mass and period parameter space we are already sensitive to based on the observational baseline, sampling, and precision of the archival RV data and for some of the targets we report new estimates of magnetic activity cycle periods, rotation periods, improved orbital parameters for previously known exoplanets, and new candidate planet signals that require further vetting or observations to confirm. Our results show that for many of these stars we are not yet sensitive to even Saturn-mass planets in the habitable zone, let alone smaller planets, highlighting the need for future EPRV vetting efforts before the launch of a direct imaging mission. We present evidence that the candidate temperate super-Earth exoplanet HD 85512b is most likely due to the star's rotation, and report a RV acceleration for δ Pav which supports the existence of a distant giant planet previously inferred from astrometry.

Exploring the densities of planets orbiting hot stars above the Kraft break

Angelica Psaridi
(Observatoire de Genève)

Co-authors: François Bouchy, Monika Lendl

Obtaining mass measurements of planets orbiting stars hotter than the Kraft break (6200 K) is inherently more difficult than for Solar-type stars. These stars have thin convective envelopes, do not efficiently generate magnetic winds, and often rotate rapidly. Consequently, they exhibit broader and fewer spectral lines, making high-precision radial velocity measurements difficult. However, characterising these planets is essential for a global understanding of planet formation and the impact of stellar mass (e.g., core-accretion models predict an increase in gas giant frequency with stellar mass).

We began a survey with CORALIE spectrograph in January 2021 to obtain mass measurements (and thus densities) of transiting planet candidates and brown dwarfs orbiting hot stars, mainly identified by the TESS mission. We obtain precise radial velocities with the cross-correlation function (CCF) technique, using a newly developed binary mask specifically designed for hot stars. We also acquired observing time on the HARPS spectrograph to further characterise planet candidates in the Saturn mass regime that require higher precision and efficiency. Our sample includes over 400 hot star planet candidates, and we find ~45% are false positives (including stellar binaries), ~20% are planets, and ~4% are brown dwarfs with the remainder yet to be characterised.

I will present recent detections (Psaridi et al. 2022, 2023) including Saturn-mass exoplanets with the least dense exoplanet ever discovered, an overview of TESS results for transiting candidates around hot stars and a global statistic of transiting planets around hot stars.

Long period RV signals in intermediate mass evolved stars: planets, oscillations or stellar activity?

Elisa Delgado Mena
(Instituto de Astrofísica e Ciências do Espaço)

The discovery of exoplanets around solar type stars and M dwarfs has been a great success in the last decades. However, the number of planets detected orbiting intermediate-mass stars is still low and several studies point to a sharp decrease in the planet occurrence around stars more massive than ~2 Msun. We present here the results of a radial-velocity (RV) survey around K giants in open clusters, the evolved counterparts of those intermediate-mass stars. Our ability to detect planets around stars with the RV method has a strong dependence on our understanding on the stellar jitter of such stars which can reach dozens of m/s in red giants. This intrinsic RV variability can be caused by stellar magnetic activity, pulsations or granulation and it behaves on a different way depending on the spectral type of the stars and on their evolutionary stage. We have found four giant planet candidates, all of them around stars with 1.6 < M/Msun < 2.5. On the other hand, for a handful of more massive stars we have detected intriguing RV signals which mimic long-period planets (P>650 days) and are stable for periods as long as 15 years. The RVs in those cases are correlated with different activity indicators (CCF-FWHM, CCF-BIS, Halpha) and we evaluate the usefulness of each indicator as a function of stellar properties. The targets presented in this work showcase the difficulties in interpreting RV data for evolved massive stars. Finally, we discuss the possibility of whether we might be facing a new kind of stellar pulsations or the RV variability is caused by long-term stellar activity. The inclusion of additional data such as the determination of magnetic field variability or RV points in the NIR will give us the final clue on the nature of the discovered signals.

Topic 1 - Atmospheres - Session 1

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14:30	15:00	00:30	James Owen
			Escape-driven evolution of exoplanets: demographic trends to compositional evolution
15:00	15:20	00:20	Daria Kubyshkina (Space Research Institute, Austrian Academy of Sciences)
			“The mass-radius relation of intermediate-mass planets outlined by hydrodynamic escape and thermal evolution”
15:20	15:40	00:20	Daniele Locci (INAF-OAPa)
			“Signatures of X-ray induced chemistry in exoplanetary atmospheres”
15:40	16:00	00:20	Jorge Fernandez (University of Warwick)
			“The atmosphere of ultra-hot Neptune LTT 9779 b survived thanks to an unusually X-ray faint star”

Escape-driven evolution of exoplanets: demographic trends to compositional evolution.

James Owen
(Imperial College London)

Close-in exoplanets are high-irradiated by their host star, heating their atmospheres to a temperature sufficient to drive a hydrodynamic outflow. For small, close-in exoplanets, this outflow is sufficiently powerful to cause an exoplanet's atmospheric bulk to evolve over its lifetime. In this talk, I will discuss the properties of these outflows, particularly what conditions cause an exoplanet's atmosphere to lose mass in core-powered mass loss or in photoevaporation. Furthermore, I'll discuss how differential escape (fractionation) of heavy elements is expected to sculpt an exoplanet's composition over its lifetime.

The mass-radius relation of intermediate-mass planets outlined by hydrodynamic escape and thermal evolution

Name: Daria Kubyshkina
(Space Research Institute, Austrian Academy of Sciences)

Co-authors: Luca Fossati

Exoplanets in the mass range between Earth and Saturn show a wide spread in radius, and thus in density, for a given mass. We aim to understand to which extent the observed radius spread is affected by the specific planetary parameters at formation and by consequent planetary atmospheric evolution.

For this purpose, we employed planetary evolution modeling to reproduce the mass–radius (MR) distribution of the 199 planets that are detected so far whose mass and radius were measured to the ≤45% and ≤15% level, respectively, and that are less massive than 108 Mearth. We simultaneously accounted for atmospheric escape, based on the results of hydrodynamic simulations, and thermal evolution, based on planetary structure evolution models. Because high-energy stellar radiation affects atmospheric evolution, we further accounted for the entire range of possible stellar rotation evolution histories. To set the planetary parameters at formation, we used analytical approximations based on formation models. Finally, we built a grid of synthetic planets with parameters reflecting those of the observed distribution.

The predicted radius spread reproduces the observed MR distribution well, except for two distinct groups of outliers comprising 20% of the population. The first group consists of very close-in Saturn-mass planets with Jupiter-like radii for which our modeling underpredicts the radius, likely because it lacks additional (internal) heating similar to the heating that causes inflation in hot Jupiters. The second group consists of warm (~400–700 K) sub-Neptunes, which should host massive primordial hydrogen-dominated atmospheres, but instead present high densities indicative of small gaseous envelopes (<1–2%). This suggests that their formation, internal structure, and evolution is different from that of atmospheric evolution through escape of hydrogen-dominated envelopes accreted onto rocky cores.

The observed characteristics of low-mass planets (≤10–15 Mearth) strongly depend on the impact of atmospheric escape, and thus of the evolution of the host star's activity level, while primordial parameters are less relevant. Instead, the parameters at formation play the dominant role for more massive planets in shaping the final MR distribution. In general, the intrinsic spread in the evolution of the activity of the host stars can explain just about a quarter of the observed radius spread.

Signatures of X-ray induced chemistry in exoplanetary atmospheres

Daniele Locci
(INAF-OAPa)

Co-authors: Giambattista Aresu, Antonino Petralia, Giuseppina Micela, Antonio Maggio, Cesare Cecchi-Pestellini

High-energy radiation from stars affects planetary atmospheres, causing departures from chemical equilibrium through photochemical processes. While extreme ultraviolet radiation dominates the upper layers, X-ray ionization and energetic photoelectrons produced by photoionization events characterize the deeper layers giving rise to a characteristic chemistry and enhancing the mixing ratio of species such as hydrocarbons. This study aims to identify photochemically induced fingerprints in high and low resolution transmission spectra of a giant planet atmosphere. We calculate transmission spectra using a code that incorporates updated infrared photoabsorption cross sections and chemical mixing ratios from a photochemical code that models high-energy ionization processes. We find that under high levels of stellar activity, the ionization process produces spectral signatures, mainly due to C2H2 and HCN, that potentially could be observed with current and future instrumentation helping us to disentangle between equilibrium and disequilibrium chemistry.

The atmosphere of ultra-hot Neptune LTT 9779 b survived thanks to an unusually X-ray faint star

Jorge Fernandez
(University of Warwick

Co-authors: Peter J Wheatley

I present XMM-Newton observations of the sun-like star LTT 9779 together with a study of the X-ray evaporation of its transiting planet, LTT 9779 b, the first ultra-hot Neptune in the middle of the Neptune desert.

The presence of LTT 9779 b so close to its star is puzzling, as the intense XUV flux it receives from its star should have stripped it of its H/He-rich atmosphere.

I find that only an X-ray faint host star is able to explain both our observations as well as the survival of its atmosphere under photoevaporation. This is consistent with both an unusually slow rotation of the star for its age, and a low measured X-ray flux.

LTT 9779 b is a super-Neptune (4.7 Earth radii, 28 Earth masses) that is consistent with the presence of a H/He envelope that constitutes 8% of its mass. The planet, with an age of 2 Gyr, orbits its solar-mass host star every 19 hours.

This planet lies in the Neptune desert, a region of the planet radius - orbital period parameter space with very few short-period Neptune-sized planets. These planets are thought to undergo substantial evaporation due to X-ray and extreme ultraviolet radiation (together, XUV) from their host stars which heats up the upper atmosphere, driving a hydrodynamic wind that can completely strip them of their volatile-rich envelopes down to a barren rocky core.

LTT 9779 b is truly unique: the only planet with an orbital period of less than a day with both measured mass and radius that maintains a significant atmosphere.

In order to find feasible evaporation pasts that can explain its current state, I simulated the XUV history of its host star by modelling its spin period evolution, as the two quantities are linked through the rotation-activity relation, where faster rotators produce higher X-ray fluxes. I confirm that the XUV history expected for a solar-mass star should have already stripped LTT 9779 b of its envelope, ruling out this scenario.

I then modelled a low-level XUV history that matches the measured upper limits for both its spin period and its X-ray luminosity, which I estimated using XMM-Newton measurements. I thus find that the planet's envelope can survive through 2 Gyr of irradiation under these conditions, starting out as a 7 Earth radii planet that has evolved to its current state through photoevaporation.

Topic 1 - Atmospheres - Session 2

Topic 1 - Atmospheres - Session 2			
16:30	16:50	00:20	Kevin France (University of Colorado)
			“Ultraviolet Observations of Exoplanet Host Stars: Inputs for Atmospheric Photochemistry and Escape Calculations”
16:50	17:10	00:20	Leonardo dos Santos (Space Telescope Science Institute)
			“Atmospheric escape of the young exo-Neptune DS Tuc Ab”
17:10	17:30	00:20	Michael Gully-Santiago (The University of Texas at Austin)
			“Observing Helium Outflows from Irradiated Exoplanets with HPF: Runaway Mass Loss”

Ultraviolet Observations of Exoplanet Host Stars: Inputs for Atmospheric Photochemistry and Escape Calculations

Kevin France
(University of Colorado)

Co-authors: Allison Youngblood (NASA/Goddard Space Flight Center)

Ultraviolet spectroscopy is a primary tool for probing the hot atmospheres of planet-hosting stars (spectral types F – M). The 10 – 320 nm ultraviolet bandpass contains key diagnostics of the full temperature range from the chromosphere to the corona, is the most sensitive bandpass for stellar flares studies, and can provide direct constraints on stellar coronal mass ejections. After their emission from the star, high-energy photons and particles regulate the atmospheric temperature structure and photochemistry on orbiting planets, influencing the long-term stability of planetary atmospheres and driving atmospheric photochemistry. As the field of exoplanet characterization has grown over the past decade, so have large ultraviolet survey programs targeting cool stars.

In this talk, I will give an overview of recent key results from ultraviolet studies of cool stars (focusing on the “extreme ultraviolet” bandpass, 10 – 91 nm), with an emphasis on implications for atmospheric photochemistry and escape. I will conclude by presenting the landscape for stellar and exoplanetary investigations utilizing ultraviolet observations over the next two decades. Missions of all sizes have important roles to play in this area: I will highlight planned or proposed missions ranging from smallsat through medium-class missions to flagships.

Atmospheric escape of the young exo-Neptune DS Tuc Ab

Leonardo dos Santos
(Space Telescope Science Institute)

Co-authors: Aline A. Vidotto, R. O. Parke Loyd, George W. King, Louise D. Nielsen, Vincent Bourrier, David Ehrenreich, Monika Lendl, Joshua D. Lothringer, Brett M. Morris

Atmospheric escape is thought to be the most important process shaping the evolution of primary atmospheres in sub-Jovian exoplanets. Models of photoevaporation predict that the bulk of the escape happens in the early lives of these exoplanets, when their host stars are the most active and thus brighter in short wavelengths relevant for the onset of escape. In this context, the 45-Myr-old gas giant DS Tuc Ab stands out one of the best targets for observations of evaporation due to host star brightness as observed from Earth. We observed three transits of DS Tuc Ab with the Hubble Space Telescope with the objective to detect its H-rich exosphere, and report on the first detection of atmospheric escape in a warm Neptune younger than 100 Myr. We found a repeatable ~20% excess absorption in both the blue and red wings of the stellar Lyman-alpha line when compared to the out of transit fluxes. Other lines in spectrum, such as Si III and N V, which are sensitive to stellar activity variations, are quiet and do not show significant variability during the transits. Additionally, we detected a flare that increases the far-ultraviolet continuum fluxes of DS Tuc A by a factor of 20 and line fluxes by a factor of a few. Although these signals suggest the presence of a large H cloud around DS Tuc Ab, detailed modeling of the atmospheric escape is necessary to interpret these observations.

Observing Helium Outflows from Irradiated Exoplanets with HPF: Runaway Mass Loss

Michael Gully-Santiago
(The University of Texas at Austin)

Co-authors: Caroline Morley and the HET Helium Exospheres Collaboration

Atmospheric escape and its associated mass loss shape the fate of exoplanets, with statistical evidence for photoevaporation imprinted across the mass-radius-insolation distribution. Searches for actively evaporating planets have ensued. The Habitable Zone Planet Finder (HPF) Spectrograph Exospheres program aims to expand the search across a diverse range of planet and host star properties via the 10830 Ångstrom Helium triplet, a sensitive probe of active atmospheric escape. Here we present a detection of >10% absorption depth during transit spectroscopy of the highly irradiated, low-gravity, inflated hot Saturn HAT-P-67b. The 13.8 hours of on-sky integration time over 41 HET tracks provides enough out-of-transit phase coverage as to reveal comparably deep absorption preceding the transit, evincing a large leading tail. This configuration can be understood as the escaping material overflowing its small Roche lobe, and advecting most of the gas into the stellar—and not planetary---rest frame, consistent with the Doppler velocity structure seen in the Helium line profiles. We, therefore, attribute the leading tail to a combination of Keplerian shear and stellar wind confinement, with preferential mass loss from dayside heating. The observation of a profoundly evaporating highly irradiated hot Saturn matches the predictions for runaway evaporation from two scenarios: Ohmic Dissipation (Batygin et al. 2011) and XUV photoevaporation (Thorngren et al. 2023). The large mass loss in HAT-P-67b naturally explains the lack of inflated sub-Saturns seen by Thorngren and Fortney (2018) as a consequence of the ephemeral lifetimes of planets in this category.

Topic 2 - Populations - Session 1

Topic 2 - Populations - Session 1			
09:00	09:30	00:30	Katia Biazzo
			Know the star to know the planet
09:30	09:50	00:20	Edward Bryant (Mullard Space Science Laboratory, UCL)
			“The Occurrence Rate of Giant Planets Orbiting Low-Mass Stars with TESS”
09:50	10:10	00:20	Matteo Pinamonti (INAF-OATo)
			“Occurrence rates of Solar System-type architectures across spectral types: a multi-technique approach”
10:10	10:30	00:20	Sheila Sagear (University of Florida)
			“The Orbital Eccentricity Distribution of Planets Orbiting M dwarfs”

Know the star to know the planet

Katia Biazzo
(INAF - Astronomical Observatory of Rome)

The wonderful progress made during the last years in the search for exoplanets has led to the discovery of a remarkable diversity of planetary systems population. The properties of the exoplanets, and in general of the planetary systems, strongly depend on the properties of the host stars: it is now clear that to know the planet with accuracy and precision it is necessary to know the star as accurately and precisely as possible. In this talk, I will present an overview of how the wide characterization of exoplanet hosting stars in terms of astrophysical parameters, elemental abundances, and kinematical properties is fundamental to constrain models of planet formation and evolution. I will also show how the composition of the planet hosting stars can be correlated with the planetary properties and can help the study of tracing the planetary migration scenario.

The Occurrence Rate of Giant Planets Orbiting Low-Mass Stars with TESS

Edward Bryant
(Mullard Space Science Laboratory, UCL)

Co-authors: Daniel Bayliss; Vincent Van Eylen

Determining the occurrence rate of giant planets as a function of the stellar mass of the host star is a critical test of the core-accretion theory of planet formation, especially for low-mass host stars (M* < 0.65 Msun; 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 determine this occurrence rate using approximately one hundred thousand nearby (d < 100 pc) low-mass stars monitored in the TESS Full Frame Images (FFIs). The all-sky monitoring of the TESS mission enables us to study this population in great detail for the first time.

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, and we will present the current results from these observations. Injection and recovery tests have been performed 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, thereby extending our understanding of giant planet populations to lower host star masses than previous studies.

We find an occurrence rate for short period giant planets across our full low-mass star sample that is significantly less than the occurrence rate of giant planets with more massive host stars, confirming the prediction of core-accretion that giant planet formation should be increasingly uncommon for lower stellar masses. More intriguingly, we find a non-zero giant planet occurrence rate for a subset of our stellar sample with masses M* < 0.4 MSun, including strong evidence for the formation of giant planets with host stars as low mass as 0.2 Msun. Our results are in contrast with the prediction that the formation of giant planets through core-accretion should be strongly inhibited for host stars with M* < 0.4 MSun, thus highlighting the need to better study the formation of exoplanets. We intepret our results in this context of planet formation and present some potential pathways for the formation of these highly exotic planetary systems.

Occurrence rates of Solar System-type architectures across spectral types: a multi-technique approach

Matteo Pinamonti
(INAF - Osservatorio Astrofisico di Torino)

Co-authors: Domenico Barbato, Alessandro Ruggieri, Alessandro Sozzetti, Aldo Bonomo, Nicola Nari, Silvano Desidera

Despite being the most abundant classes of known exoplanets, super-Earths and sub-Neptunes are absent in our Solar System, and the exact reason for this is still unknown. However, some models suggest that cold-Jupiter planets prevent the formation of inner super Earths, and that this could be in fact the reason for their absence in our Solar System.

In this framework, we take advantage of high-resolution echelle spectroscopy from HARPS-N@TNG, and high-precision astrometric data from Gaia to study planetary systems across different spectral types. First we present the high-cadence and high-precision Radial Velocity (RV) monitoring of stellar hosts to long-period giants with well-measured orbits, in search for short-period low-mass planets, conducted with HARPS-N over a large sample stars, from M-dwarf to Solar-type stars. We then present the combination of RV measurements and high-precision Gaia astrometry, that can greatly expand our knowledge of the long-period planets orbiting the observed systems. We show how the combination of RV information with proper-motion anomalies from GaiaDR3 and Hipparcos can measure the inclination and real masses of several long-period companions in our observed systems, and present a novel set of simulations of Gaia DR4 astrometric time series that, when combined with the RV data at our disposal, quantify the great boost in precision that these data will bring to the study of long-period exoplanetary companions. Finally, from an homogeneous Bayesian analysis of the observed sample, we highlight a very different behavior between G- and M-dwarfs: in the G-sample, the frequency of Super-Earths appears to be diminished by the presence of cold Jupiters, while the opposite is observed for M dwarfs.

The presented results provide an important advancement in discriminating between proposed outcomes of different processes for the formation of super Earths in the presence of outer giant companions, and produce the first direct observation of a different influence of cold Jupiters in the formation of planetary systems around stars of different masses.

The Orbital Eccentricity Distribution of Planets Orbiting M dwarfs

Sheila Sagear
(University of Florida)

Co-authors: Sarah Ballard, Adrian Price-Whelan

Exoplanet orbital eccentricities encode key information about planetary system formation and evolution. For M dwarf planets in particular, the proximity of the habitable zone to the host star makes eccentricity additionally important for understanding habitability. We investigate the underlying distribution of orbital eccentricities for planets around early-to-mid M dwarf host stars. We employ a sample of 163 planets around early- to mid-M dwarfs across 101 systems detected by NASA's Kepler Mission. We constrain the orbital eccentricity for each planet by leveraging the Kepler lightcurve with a stellar density prior, constructed using metallicity from spectroscopy and stellar parallax from ESA's Gaia mission. Within a Bayesian hierarchical framework, we extract the underlying eccentricity distribution for both single- and multi-transit systems. The data suggest the possibility of distinct dynamically warmer and cooler sub-populations within the single-transit distribution: the single-transit data prefer a mixture model composed of two distinct Rayleigh distributions, one preferring higher eccentricities and one lower eccentricities, over a single Rayleigh distribution with 7:1 odds. We contextualize our findings within a planet formation framework by comparing them to analogous results in the literature for planets orbiting FGK stars. By combining our derived eccentricity distribution with other M dwarf demographic constraints, we estimate the underlying eccentricity distribution for the population of early- to mid-M dwarf planets in the local neighborhood. Comparisons between the eccentricity distribution for singly- and multiply-transiting systems, as well as the distribution between M dwarfs and FGK dwarfs, help illuminate the dynamical states of M dwarf planets at a population level. Extending this work, we construct a flexible stellar age prediction model by combining stellar rotation information with age-correlated galactic kinematics information from Gaia for a calibration sample of roughly 50,000 stars. We use this model to estimate ages for Kepler M dwarfs, and constrain their metallicities using Gaia color-magnitude information and spectral data from the SDSS APOGEE survey. We investigate possible relationships between M dwarf stellar properties and the occurrence and dynamics of their planetary systems.

Topic 2 - Populations - Session 2

Topic 2 - Populations - Session 2			
11:00	11:20	00:20	Emily Pass (CA/Harvard-Smithsonian)
			“The Volume-Complete Survey of Mid-to-Late M Dwarfs within 15pc: Insights on the Spindown of Fully Convective Stars and the Rarity of Jupiter Analogs”
11:20	11:40	00:20	Jesús Maldonado (INAF-OAPa)
			“M dwarfs analysis and characterisation of exoplanets”
11:40	12:00	00:20	Heather Johnston (University of Leeds)
			“Giant planet formation around intermediate-mass stars”
12:00	12:20	00:20	Bárbara Soares (IA)
			“Assessing the processes behind planet engulfment and its imprints”
12:20	12:40	00:20	Jingyi Mah (MPIA)
			“Forming super-Mercuries: The role of stellar abundances”

The Volume-Complete Survey of Mid-to-Late M Dwarfs within 15pc: Insights on the Spindown of Fully Convective Stars and the Rarity of Jupiter Analogs

Emily Pass
Center for Astrophysics | Harvard & Smithsonian

Co-authors: Jennifer Winters, David Charbonneau, Jonathan Irwin, Amber Medina, David Latham, Perry Berlind, Michael Calkins, Gilbert Esquerdo, Jessica Mink

We report results from the volume-complete spectroscopic survey of low-mass (0.1-0.3Msun) M dwarfs within 15pc, focusing on the 323 of these stars without close binary companions. Understanding low-mass M dwarfs is critical, as they host the only terrestrial planets whose atmospheres are spectroscopically accessible with JWST. Between 2016 and 2022, we collected four observations of each star using high-resolution spectrographs on 1.5m telescopes. For the 200 Hα-inactive stars, we do not detect any radial-velocity variables. We use this null detection to place constraints on the occurrence rate of giant planets around low-mass M dwarfs. At the snow line (100 K < Teq < 150 K), we place 95%-confidence upper limits of 1.5%, 1.7%, and 4.4% for 3MJ < Msini < 10MJ, 0.8MJ < Msini < 3MJ, and 0.3MJ < Msini < 0.8MJ giant planets; i.e., Jupiter analogs are rare around low-mass M dwarfs, with profound implications for the formation and evolution of their habitable-zone terrestrial planets. Understanding the activity history of low-mass M dwarfs is also important, as their planets formed and evolved during a protracted period of intense radiation and particle flux, potentially stripping planetary atmospheres. For the 123 Hα-active stars, we measure rotation periods, Hα equivalent widths, rotational broadening, inclinations, and radial velocities. We establish that 92+/-3% of active, low-mass M dwarfs rotate with periods shorter than 20 days, with 74+/-4% rotating with periods less than 2 days. Our results are consistent with the developing consensus that fully convective M dwarfs spin down abruptly, transitioning between a rapidly rotating, Hα-active mode and a slowly rotating, Hα-inactive mode. We identify a population of stars in the transition region with enhanced Hα emission and flaring rates, which may result from the processes responsible for their rapid loss of angular momentum. Many of the active stars exhibit activity-induced radial-velocity variability, which we link to their rotational broadening and photometric variability using a simple starspot model.

M dwarfs analysis and characterisation of exoplanets

Jesus Maldonado
(INAF - Osservatorio Astronomico di Palermo)

Most stars in our immediate neighbourhood are not like the Sun. The largest (by number) stellar population in the solar neighbourhood is constituted by low-mass (or M dwarfs) stars. At the same time, M dwarfs have been recognised as important targets for exoplanet surveys. However, unlike their solar-type counterparts, the stellar properties of M dwarfs are poorly constrained. In this contribution, we will show how the uncertainties in the stellar parameters of M dwarfs host stars have a significant impact in the determination of the planetary bulk composition and discuss recent approaches to determine the stellar parameters and abundances of M dwarfs: from the use of pseudo-equivalent widths to dimensionality reduction and sparse Bayesian methods. Finally, we will discuss the demographics of exoplanets orbiting around M dwarfs as a function of the properties and environmental conditions of the host stars (mass, iron content, and chemical abundances).

Giant planet formation around intermediate-mass stars

Heather Johnston
(University of Leeds)

Co-authors: Olja Panic, Beibebi Liu

We carry out a pebble-driven planet formation simulations to investigate the formation of giant planets around intermediate-mass stars, in the stellar mass range between 1.5 $M_\odot$ and 3 $M_\odot$. We find that the massive giant planets are preferred to emerge in the circumstances when the disks have larger sizes, metallicities, and/or higher disk accretion rates. As these properties are only enhanced with stellar mass, an alternative physical scenario is needed to explain the decline of giant planet frequency from 2 to 3 $M_\odot$. We propose that FUV/EUV photoevaporation in this stellar mass range plays a role in actively removing the disc, and slowing down planet formation. This photoevaporation mechanism is only dominant after the first 2Myr, meaning that, in this scenario, giant planets form predominantly later than the first couple of Myr of disc evolution. This is not in contradiction with the ~2Myr disc lifetimes found observationally, because only a small fraction of stars (long-lived discs) end up becoming giant planet hosts.

Assessing the processes behind planet engulfment and its imprints

Bárbara Soares
(Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto)

Co-authors: Vardan Adibekyan, Christoph Mordasini, Sérgio Sousa, Elisa Delgado-Mena, Nuno Santos

Newly formed stars are surrounded by a protoplanetary disk. A fraction of this disk material condenses into planet-forming blocks, and most of it eventually accretes onto the star within a few million years, up until the dissipation of the disk. The final composition of stars thus depends on the specific composition of the accreted material. Accretion of the metal-rich planetary material onto their host stars (i.e., the in-fall of planets) may result in a modification of the stellar surface composition. Moreover, a chemical imprint due to planet engulfment can depend not only on the disk lifetime, but also on the stellar age, as a large convective layer would prevent an observable change in the stellar composition. Very recently, Spina et al. proposed that around 30% of Sun-like stars experience planet engulfment that alters their composition.

We have analyzed the most recent data from the New Generation Planetary Population Synthesis (NGPPS) calculations by the Generation III Bern model which simulates the formation and evolution of 1000 planetary systems across 10 Gyr. I propose an oral contribution to present our new findings on the timing, mechanisms, and occurrence rate of planet engulfment around Sun-like stars, and the consequences of the results for stellar chemical anomalies.

Forming super-Mercuries: The role of stellar abundances

Jingyi Mah
(Max Planck Institute for Astronomy)

Co-authors: Bertram Bitsch

We investigated the formation of iron-rich rocky exoplanets, also termed 'super-Mercuries', via pebble accretion in discs around their respective host stars. This is done using a disc evolution model which includes the evaporation and condensation of pebbles at various evaporation fronts in the disc, as well as accounting for stellar abundances when computing the initial disc composition. We find that a low disc viscosity is favourable for the formation of super-Mercuries. The combined effects of long viscous evolution and orbital migration timescales in low-viscosity discs facilitate the growth of iron-rich planets near the iron evaporation front. Furthermore, we also find a decreasing trend in planet iron mass fraction with increasing stellar Mg/Si ratio, which implies that super-Mercuries are more likely to form around stars with low Mg/Si, in agreement with observational data.

Topic 1 - Atmospheres - Session 3

Topic 1 - Atmospheres - Session 3			
14:30	15:00	00:30	Benjamin Rackham
			The impact of stellar activity on the detection and characterization of exoplanetary atmospheres: challenges and opportunities
15:00	15:20	00:20	William Dethier (IPAG)
			“Combined analysis of stellar and planetary absorption lines via global forward-transit simulations”
15:20	15:40	00:20	Hritam Chakraborty (Geneva Observatory, Univ. Geneva)
			“Constraining the impacts of stellar activity on transmission spectroscopy”
15:40	16:00	00:20	Adrien Deline (University of Geneva)
			“Probing ultra-hot Jupiters with CHEOPS phase curves”

The impact of stellar activity on the detection and characterization of exoplanetary atmospheres: challenges and opportunities

Benjamin Rackham
(Massachusetts Institute of Technology)

Transmission spectroscopy, a method for studying exoplanetary atmospheres by measuring the wavelength-dependent radius of a planet as it transits its star, relies on a precise understanding of the spectrum of the star being occulted. However, stars are not homogeneous, constant light sources but have temporally evolving photospheres and chromospheres with inhomogeneities like spots, faculae, and plages. Study Analysis Group 21 (SAG21) of NASA's Exoplanet Exploration Program Analysis Group (ExoPAG) was organized to study the effect of stellar photospheric heterogeneity on low-resolution transmission spectroscopy. This SAG brought together an interdisciplinary team of more than 100 scientists, with observers and theorists from the heliophysics, stellar astrophysics, planetary science, and exoplanetary atmosphere research communities, to study the current needs that can be addressed in this context to make the most of transit studies from HST, JWST, and more. Here I report on the main conclusions of this analysis, highlighting outstanding challenges, mitigation efforts underway, and connections to high-resolution observations. The analysis produced 14 findings, which fall into three science themes that encompass (1) the Sun as the stellar benchmark, (2) surface heterogeneities of other stars, and (3) mapping stellar knowledge to transit studies. Addressing the needs identified through this large community effort will ensure that we can optimally leverage transmission spectra in light of stellar activity.

Combined analysis of stellar and planetary absorption lines via global forward-transit simulations

William Dethier
(IPAG)

Co-authors: Vincent Bourrier

Transit spectroscopy of exoplanets has led to significant progress in understanding the atmospheric structure and dynamics of these planets. However, improvements in resolution and sensitivity have also revealed potential biases induced by the occultation of stellar lines by the planet during its transit. We use the EVaporating Exoplanets (EVE) code to generate realistic stellar spectra during exoplanet transits, accounting for the 3D geometry of the system's architecture and atmospheric structure, and for stellar line variations over the stellar disc. This allows us to characterize the planet-occulted line distortions (POLDs) in transmission spectra that arise from proxies used for the occulted stellar lines. We investigate the impact of POLDs on atmospheric absorption signatures as well as their dependence on stellar rotation, centre-to-limb variations, and broadband limb-darkening. Using our approach we reinterpret existing transit data of two well-known exoplanets to distinguish between their planetary absorption signatures and POLDs. With the upcoming generation of high-resolution spectrographs such as NIRPS/VLT and ANDES/ELT, contamination from POLDs will be a dominant source of noise in many transit datasets. More than ever, accounting accurately for the impact of the stellar lines occulted by the planets will be decisive in characterising their atmosphere.

Constraining the impacts of stellar activity on transmission spectroscopy

Hritam Chakraborty
(Geneva Observatory, University of Geneva)

Transmission spectroscopy is a proven technique to study the composition and structure of a transiting exoplanet's atmosphere. However, stellar surface inhomogeneities, such as spots and faculae, can alter the observed transmission spectra and bias the inferred atmospheric properties. This is referred to as stellar contamination of transmission spectra. Due to the variable nature of the stellar activity, it is also difficult to stitch together or compare multi-epoch observations, and evaluate any potential variability in the exoplanet's atmosphere. In my talk, I intend to present a new tool: Stellar Activity Grid for Exoplanets (SAGE; Chakraborty et al. in preparation), developed to constrain and remove the time-dependent impact of stellar activity on transmission spectra. It uses a pixellation approach to map the stellar surface, along with activity features such as spots and faculae, onto a two-dimensional Cartesian grid while fully accounting for limb-darkening and rotational line-broadening effects. With SAGE, we studied the impact of stellar contamination on the transmission spectra of planets orbiting F to M-type stars. We find a clear correlation between the amplitude of stellar contamination and the effective temperature of the star, with cooler stars having much stronger contamination. Due to limb darkening, stellar contamination is also dependent on the location of the active regions. For a spot closer to the centre of the stellar disc, limb-darkening increases the impact of stellar contamination. On the contrary, for a spot closer to the limb, the contamination is suppressed. Moreover, due to the chromaticity of limb darkening, the stellar contamination also has a strong colour dependence. Finally, SAGE can also be used to map the surface of individual stars using the rotationally modulated flux variability of the star, thus allowing us to couple the photometric variability to the stellar contamination of transmission spectra. Furthermore, I will discuss how simultaneous, multi-filter monitoring of stars from ground-based facilities can be vital in breaking the classical degeneracy associated with inferring the properties of the active regions.

Probing ultra-hot Jupiters with CHEOPS phase curves

Adrien Deline
(University of Geneva)

Co-authors: CHEOPS consortium

Ultra-hot Jupiters' are gas giants that orbit very close to hot and massive early-type stars. Their atmospheres undergo extreme conditions with dayside temperatures that can reach that of the coldest stars. The composition of their gaseous envelope is dominated by ions and dissociated molecules, which inhibit global circulation leading to inefficient heat redistribution and strong day-to-night temperature gradients. These atmospheric properties create a large thermal emission contrast between the dayside and the nightside of ultra-hot Jupiters, making them particularly amenable to atmosphere mapping with observations at various phase angles. Photometric observations of these extreme worlds at different orbital phases (transit, occultation, phase curve) provide access to several key properties of their atmospheres, especially when combining visible and infrared observations.

In this talk, we will present results from photometric phase-curve observations of ultra-hot Jupiters made with the instrument CHEOPS. We derive constraints the planetary atmosphere such as its dayside temperature and heat redistribution efficiency. We also detail how such observations can provide insights on the stellar properties and the system architecture.

Topic 1 - Atmospheres - Session 4

Topic 1 - Atmospheres - Session 4			
16:30	16:50	00:20	Michal Steiner (Geneva Observatory)
			“Characterizing transiting exoplanets with high-resolution spectroscopy”
16:50	17:10	00:20	Erik Meier Valdés (Center for Space and Habitability, University of Bern)
			“An exploration of the visible phase curve variability of the super-Earth 55 Cnc e with CHEOPS”
17:10	17:30	00:20	Ana Rita Costa Silva (IA)
			"Neutral iron detection in dayside emission spectra of WASP-76b"

Characterizing transiting exoplanets with high-resolution spectroscopy

Michal Steiner
(Observatory of Geneva)

To date, more than 5300 exoplanets have been discovered so far. Most of these systems are detected with the transits orbiting on short orbits. One of the main populations on short orbits are hot-Jupiters, planets the size of Jupiter but with periods of several days. This type of planet can be very inflated, suggesting a significant atmosphere. To characterize their atmospheres, we can utilize the transmission spectroscopy method, which uses the transit geometry and characterize it spectroscopically.

This method allows us to probe atmospheric composition and dynamics. Furthermore, with the analysis of the Rossiter-McLaughlin effect (happening due to stellar rotation and partial stellar occultation by the planet during the transit), we can analyze the projected spin-orbit angle (obliquity).

In this talk, I will show my work on HARPS and ESPRESSO datasets, focusing on characterizing the spin-orbit angle and detecting species in the atmosphere, such as sodium, excited hydrogen, and potassium in the transmission spectrum.

An exploration of the visible phase curve variability of the super-Earth 55 Cnc e with CHEOPS

Erik Meier Valdés
(Center for Space and Habitability, University of Bern)

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Among the handful of super-Earth exoplanets discovered, 55 Cnc e is arguably the most studied one and yet its true nature is still shrouded in mystery. Past observations in the optical range detected a modulation phased with the planetary orbital period too large to be explained by reflected light and thermal emission alone. Moreover, extensive observations revealed a variable phase curve amplitude and offset. The process causing the phase modulation and offset remains unknown, but hypotheses include volcanic activity, the presence of an inhomogeneous circumstellar torus of dust, star-planet interaction due to the short separation to its host star, among others. The CHaracterising ExOPlanet Satellite (CHEOPS) observed 55 Cnc a total of 29 times, comprising around 800 observing hours, between March 2020 and February 2022 to investigate the occultation and phase curve variability in the optical range. Here we present the results of the CHEOPS campaign on the phase curve properties and a study the plausibility of the hypothesis of a circumstellar torus of dust as responsible for the variability observed in the system. In particular, we present the sublimation timescales of different dust composition and sizes and its motion around the star once it escapes the planet. Future observations with JWST promise further insight into this iconic super-Earth.

Neutral iron detection in dayside emission spectra of WASP-76b

Ana Rita Costa Silva
(Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto)

Co-authors: A. R. Costa Silva, O. Demangeon, N. C. Santos

Characterising exoplanets and their atmospheres is a crucial step in the quest for life outside of Earth. In favourable cases, we can directly observe the light emitted from an exoplanet's dayside and utilise high-resolution spectroscopy and cross-correlation techniques to detect the molecular and atomic species present in its atmosphere.

Recently, the transmission spectra of WASP-76 b revealed an asymmetric signature of neutral iron (Ehrenreich et al. 2020, Kesseli & Snellen 2021). The authors proposed a scenario where iron condensed on the nightside, and predicted that this species would be amenable to detection on the dayside through thermal emission spectroscopy.

To test this hypothesis, we analysed four time-series emission spectra of WASP-76 b obtained with the high-resolution ESPRESSO spectrograph. The dayside observations were carried out before and after the secondary transit (two epochs of each), probing the eastern and western hemispheres of the tidally locked planet. We extracted the exoplanet's spectra and cross-correlated them with an iron mask created for an ultra-hot Jupiter with a temperature inversion in its atmosphere.

We found 3-sigma detections of neutral iron on the dayside of WASP-76 b in at least two epochs. The discrepancy between datasets is examined and we propose explanations for the lack of detection during the other two epochs.

Topic 3 - Dynamics - Session 1

Topic 3 - Dynamics - Session 1			
09:00	09:30	00:30	Antoine Strugarek
			Detectability of star-planet magnetic interactions
09:30	09:50	00:20	Joseph Callingham (ASTRON / Leiden University)
			"Radio stars and exoplanets at low-frequencies: First detections"
09:50	10:10	00:20	John Barnes (Open University)
			"Planet Discoveries from the Dispersed Matter Planet Project"
10:10	10:30	00:20	Alexandre Correia (University of Coimbra)
			"Asynchronous rotation for Earth-like planets in the habitable zone of M-dwarf stars"
10:30	10:50	00:20	Maria Helena Moreira Morais (UNIVERSIDADE ESTADUAL PAULISTA (UNESP))
			"Retrograde resonances in extrasolar systems"

Detectability of star-planet magnetic interactions

Antoine Strugarek
(CEA Paris-Saclay)

Over the last two decades, a large population of close-in planets has been detected around a wide variety of host stars. Such planets are thought to strongly interact with their host star by means of the irradiation they receive, the tidal forces they induce, as well as their interaction with the ambient magnetised stellar atmosphere and wind they orbit in. Can we use these interactions to better constrain these planets and their hosting stars? And where does this population of hot planets originate from?

The properties of the host star determine the key ingredients at the heart of these interactions. The stellar spectrum is the primary driver of the interaction in the upper atmosphere of exoplanets. The stellar structure determines its response to the tidal forcing from his hot exoplanet. Finally, the stellar global magnetic field is at the heart of star-planet magnetic interaction: its strength sets the magnetic energy available for the interaction, its shape determines the connection path between the star and the planet, and its temporal modulation (e.g. magnetic cycles) is at the source of an on/off behavior of the magnetic interaction.

I will give an overview of our understanding of star-planet magnetic interactions. I will focus on describing short term —intra-orbit— and long term —secular— effects of these interactions. I will reflect on our present capability to detect and characterise them, both in individual systems and in the hot exoplanets population. When detected, star-planet interactions indeed provide a fantastic opportunity to better understand the environment of the host star, as well as the properties of the exoplanet triggering them.

Radio stars and exoplanets at low-frequencies: First detections

Joseph Callingham
(ASTRON / Leiden University)

One key question that astronomy is attempting to answer is whether there are habitable planets around stars other than our Sun. While we have entered an era where identifying nearby exoplanets has become standard, discerning whether the environmental conditions dictated by the host stars are suitable for life has proved far more elusive. The detection of low-frequency radio emission from an M dwarf or an exoplanet provides a direct probe of extrasolar space weather and the planet's magnetic field - information crucial for assessing the potential habitability of the planet. In this talk, I will outline our LOFAR survey of stellar systems, with a focus on our recent detection of strong, highly circularly polarised low-frequency radio emission associated with nearby stars - the expected signpost of star-exoplanet interactions. I will discuss how our survey represents the most comprehensive observations of stellar systems at low frequencies, and the implications of this new population in understanding the magnetosphere of M dwarfs and exoplanetary magnetic fields. I will conclude with our progress in determining the expected periodicity of the radio emission from star-planet interactions.

Planet Discoveries from the Dispersed Matter Planet Project

John Barnes
(Open University)

Co-authors: C.A. Haswell, G. Anglada-Escudé, J. Cooper, M.R. Díaz, J.P.J. Doherty, L. Fossati, J.S. Jenkins, J. Llama, C. McCune, P.A. Peña Rojas, M.G. Soto, D. Staab, M.R. Standing, M. Waller-Bridge

The Dispersed Matter Planet Project targets bright, V < 10, FGK dwarf stars within 100 pc with signs of circumstellar absorption in archive spectra. The absorption is caused by mass loss from close-in planets. Using a carefully selected sample of candidate systems showing absorption signatures, we are conducting high cadence radial velocity surveys to search for planets with short periods.

I will discuss some of the most recent discoveries of the project. The planets we are identifying are in diverse systems and include close orbiting gas giants, low-mass multiplanet systems and planets in binaries. Many of our candidates will transit with signatures below TESS sensitivities. The on-going mass loss will reveal the processes creating the Neptune desert and radius valley. I will discuss our targets in the context of the wider population of short period, hot planets that will be predominantly studied with Ariel and JWST.

Asynchronous rotation for Earth-like planets in the habitable zone of M-dwarf stars

Alexandre Correia
(University of Coimbra)

Co-authors: Ema Valente

Close-in planets undergo strong tidal interactions with the parent star that modify their spins and orbits. It is commonly assumed that the rotation of these planets is synchronous and the planet spin axis is aligned with the normal to the orbit (zero planet obliquity). Here we show that, for Earth-like planets in the habitable zone of M-dwarf stars the rotation rate can be trapped in spin–orbit resonances that delay the evolution towards the synchronous state. More interestingly, we observe that capture in some spin–orbit resonances may also excite the obliquity to high values rather than damp it to zero. Depending on the system parameters, obliquities up to 80 degrees can be maintained throughout the entire lifetime of the planet. These unexpected spin states may help to sustain temperate environments and thus more favourable conditions for life.

Retrograde resonances in extrasolar systems

Maria Helena Moreira Morais
(UNIVERSIDADE ESTADUAL PAULISTA (UNESP), BRASIL)

Co-authors: CARITÁ, G.A.; SIGNOR, A.C.; EGYDIO DE CARVALHO, R.; PRADO, A.F.B.A.

The formation of a planetary system occurs from a cloud of interstellar gas and dust which because of its rotation converges to a disk, thus most objects in the solar system have approximately coplanar motion in the same direction as the rotation of the Sun (prograde motion). However, small bodies that move in the opposite direction to the planets (retrograde motion) exist in the solar system and should also exist in other planetary systems. Recent theoretical work showed that these small bodies on retrograde orbits may be in resonant configurations with the planets and several examples have been identified in the solar system. Moreover, numerical studies show that encounters between stars can generate systems whose planets have orbits with high relative inclinations, and that retrograde planets may also be captured in binary star systems. In these extrasolar planetary systems, the resonant locations are preferential zones to guarantee stability.

We will present results regarding the stability of the main retrograde resonances (1/1, 2/1, 1/2, 3/1, 1/3, 4/1, 1/4, 3/2, 2/3) for three-body systems consisting of a solar mass star, a Jupiter sized planet and an additional planet with mass equal to either Neptune, Saturn or Jupiter. These results show which resonant retrograde configurations are possible and thus may be used as a guide to search for such exoplanetary systems. Moreover, we also survey retrograde orbits around binary stellar systems with mass ratio between 0.01 (hierarchical masses) and 0.5 (equal masses) in the framework of the planar circular restricted three-body problem. We conclude that retrograde resonances occur in binary star systems up to high mass ratio and show some examples. These results may be used to identify retrograde planets in binary star systems.

Topic 2 - Populations - Session 3

Topic 2 - Populations - Session 3			
11:20	11:50	00:30	Bertram Bitsch
			Stellar abundances and their role in bulk compositions of planets
11:50	12:10	00:20	Kiersten Boley (The Ohio State University)
			“Metallicity Cliff: An Abrupt drop in Super-Earth Occurrence around Metal-Poor Stars”
12:10	12:30	00:20	Tim Hallatt (McGill University-iREx)
			“On the Formation of Planets in the Milky Way's Thick Disk”
12:30	12:50	00:20	Amadeo Castro-González (CAB)
			“Exploring TOI-244 b and the growing population of low-density super-Earths”
12:50	13:10	00:20	Thomas Wilson (University of St Andrews)
			“The first four planet M-dwarf system spanning the radius valley contains a rocky, long-period body”

Stellar abundances and their role in bulk compositions of planets

Bertram Bitsch
(MPIA)

Abstract: The overall framework for planet formation via the core accretion scenario can explain the vast majority of the occurrence rates of super-Earths/mini-Neptunes and giant planets. However, these planet formation models are now challenged by a new component: the bulk composition of planets, adding even more complexity. One important ingredient of these models is the assumption that the stellar abundance is a proxy for the original composition of the disc. Despite the fact that detailed stellar abundances span over a wide range, planet formation models mostly used solar abundances up until a few years ago. Only recently has the idea that detailed stellar abundances (Fe, Mg, Si, O, C) play an important role for planet formation and composition been included in models. In this talk, I will review how bulk compositions of planets can be determined and how they are influenced by stellar abundances within a planet formation framework. Consequently, I will show that it is essential to understand the star before we can begin to understand the planets that surround it.

Metallicity Cliff: An Abrupt drop in Super-Earth Occurrence around Metal-Poor Stars

Kiersten Boley
(The Ohio State University)

Co-authors: Jessie Christiansen, Jon Zink, and Kevin Hardegree-Ullman

Planet formation models predict that below a certain protoplanetary disk metallicity, the surface density of solid material is too low to form planets via core accretion. Previous studies have indicated that short-period planets preferentially form around stars with solar and supersolar metallicities. These findings suggest that it may be challenging to form planets within metal-poor environments. There have been few surveys of metal-poor stars that are sensitive to small planets, and as such, there is little constraint on planet occurrence rates for stars below [Fe/H] ~-0.4. This metallicity is still above the predicted metallicities that planet formation is suppressed. Expanding upon previous works, we constructed a large sample of ~100,000 metal-poor stars observed by TESS with spectroscopically-derived stellar parameters. With this large catalog, we probed planet formation within the metal-poor regime ($-1.0 \leq [Fe/H] \leq -0.25$) placing the most stringent upper limits on planet occurrence rates around metal-poor stars to date. Our results suggest the presence of a metallicity cliff for super-Earths that may indicate the initial point at which small planet formation is quenched.

On the Formation of Planets in the Milky Way's Thick Disk

Tim Hallatt
(McGill University; Trottier Space Institute; Institute for Research on Exoplanets (iREx))

Co-authors: Eve J. Lee

Recent exoplanet demographics studies have revealed that super-Earths residing in the Milky Way's thick disk are half as common as their counterparts in the galaxy's thin disk, and exhibit lower multiplicity. I will explore the hypothesis that radiative feedback from the stellar nursery in which these planets were born can inhibit the formation of rocky planets at small (~0.1 au) scales. In particular, I will highlight that the irradiation conditions in the primordial thick disk can readily photoevaporate protoplanetary disks. My results suggest that thick disk planetary systems may serve as laboratories for understanding the extent to which the galactic environment and formation pathway of a planetary system are intertwined. This subfield of exoplanet science is burgeoning with new measurements from K2 and TESS that will probe deeper into the Milky Way’s disk, and the ancient planetary systems that reside there.

Exploring TOI-244 b and the growing population of low-density super-Earths

Name: Amadeo Castro-González
(Centro de Astrobiología)

Co-authors: Jorge Lillo-Box

Small planets located at the lower mode of the bimodal radius distribution are generally assumed to be composed of iron and silicates in a proportion similar to that of the Earth. However, recent discoveries are revealing a new group of low-density planets that are inconsistent with that description. Their low densities could be explained by a scarcity of iron within their cores, by the presence of a significant amount of volatile elements, or by both effects. Recently, Adibekyan et al. found that stars with higher Mg/Fe and Si/Fe ratios host lighter super-Earths, which indicates a compositional star-planet connection. However, the lowest-dense super-Earths cannot be explained by having an iron-poor core, and instead require a significant amount of volatile elements in their compositions. The reason why those planets have such large amounts of volatiles is still unknown. In this talk, I will present our recent characterization of the unusually low-density super-Earth TOI-244 b based on ESPRESSO and TESS data and discuss its possible composition. Besides, I will present two tentative trends in the density-metallicity and density-insolation parameter space that might hint at the formation and composition of the lowest-density super-Earths.

The first four planet M-dwarf system spanning the radius valley contains a rocky, long-period body

Thomas Wilson
(University of St Andrews)

Co-authors: The CHEOPS and HARPS-N Consortia

One of the most important exoplanet demographic discoveries, the radius valley, has been well-modeled by formation (i.e. gas-poor/-depleted) and evolution (i.e. photoevaporation and core-powered mass-loss) that hints at the underlying physical process that sculpt the gap. Observational follow-up studies found that the valley properties vary as a function of planet equilibrium temperature, and stellar type and age. An interesting early result found that the M-dwarf valley has different properties to FGK-dwarfs potentially meaning that different formation and evolution process impact planets around these low-mass stars. However, the number of well-characterised planets around M-dwarf is limited with long-period (P>20d) bodies particularly poorly represented.

In this presentation, I will report the discovery and characterisation of the first four planet M-dwarf system spanning the radius valley using the TESS and CHEOPS spacecraft, and HARPS-N and ground-based photometric facilities. From transit photometry and RV analysis we conducted Bayesian internal structure modelling and find that this likely kinematic thick disk star hosts a interior rocky planet (b), two gaseous bodies (c & d), and an exterior likely rocky planet (e) with an orbital period of ~29d. Interestingly, planet e is both smaller and denser than the interior planets c and d, and resides above model predictions for the radius valley that this period, making planet e the only body in this parameter space. The properties of this unprecedented system provides strong evidence for the gas-depleted formation of planets around M-dwarfs and will likely become a key target for future atmospheric studies.

Topic 2 - Populations - Session 4

Topic 2 - Populations - Session 4			
09:00	09:30	00:30	Giovanna Tinetti
			atm composition, population studies - TBD
09:30	09:50	00:20	Anna Shapiro (MPS)
			“Planetary UV stress intensifies with stellar metallicity”
09:50	10:10	00:20	David Coria (University of Kansas)
			“CNO Isotope Ratios Across Exoplanet Systems: Implications for Planet Formation and Atmospheric Composition”
10:10	10:30	00:20	David Charbonneau (Harvard University)
			“The Occurrence Rate of Terrestrial Planets Orbiting Nearby Mid-to-late M Dwarfs”

Chemical trends: from individual planets to populations

Giovanna Tinetti
(University College London)

Population studies of exoplanets are key to unlocking their statistical properties. So far, the inferred properties have been mostly limited to planetary, orbital, and stellar parameters extracted from, e.g., Kepler, radial velocity, and Gaia data. More recently an increasing number of exoplanet atmospheres have been observed from space and the ground. With a few exceptions, these atmospheric studies have mainly focused on individual planets and their stellar hosts. With the recent launch of Webb and the planned launch of Roman and Ariel before the end of this decade, population-based studies of exoplanet atmospheres, together with their stellar hosts, will offer an unparalleled opportunity to uncover chemical trends and how they correlate with stellar/planetary/orbital parameters. This information will be key to guide our understanding of formation and evolution mechanisms of the planets in our galaxy.

Planetary UV stress intensifies with stellar metallicity

Anna Shapiro
(Max Planck Institute for Solar System Research, Goettingen, Germany)

Co-authors: Christoph Brühl, Klaus Klingmüller, Benedikt Steil, Alexander I. Shapiro, Veronika Witzke, Nadiia Kostogryz, Laurent Gizon, Sami K. Solanki, and Jos Lelieveld

Ozone, a minor constituent of the Earth's atmosphere, is produced photochemically from molecular oxygen. Both ozone and oxygen protect the biosphere against harmful ultraviolet (UV) radiation. But what would happen to this protection if the Earth were hosted by another solar-like star? While it is known that UV protection depends on the effective temperature of a host star, the effect of metallicity which is another important stellar parameter has not been addressed until now.

Here we close this knowledge gap by modelling the planetary atmospheres of Earth twins hosted by stars with near-solar effective temperatures (5300 to 6300 K) and a broad range of metallicities. Paradoxically, although metal-rich stars emit substantially less UV radiation than metal-poor stars, we find that the surface of their planets is exposed to higher UV fluxes. This is because the radiative flux that induces ozone formation decreases more strongly with metallicity than that causing ozone loss. Further, the atmospheric oxidation (cleaning) capacity is remarkably stable and life-supporting almost independent of stellar metallicity at an oxygen volume fraction above 1%. These findings imply that planets in the habitable zones of stars with low metallicity are the best targets to search for complex life on land.

CNO Isotope Ratios Across Exoplanet Systems: Isotope Analysis in Cool Dwarf Exoplanet Hosts

David Coria
(University of Kansas)

Co-authors: Ian Crossfield, Neda Hejazi

To date, there are still only a handful of dwarf star isotopic abundances in the literature and even fewer of those are from exoplanet host stars. Past isotopic searches have been hindered by limited sensitivity and resolution, strong telluric absorption, and the opacity due to millions of other molecular absorption lines that dominate the observed spectrum of cool stars. Now, isotopic abundance analysis is possible via high resolution spectroscopy and is the next logical step for many cool exoplanet host stars. Because the interpretation of planetary isotope ratio measurements directly depends on complementary host star measurements, it is of the upmost importance to build the stellar isotopic abundance database-- especially as novel isotope detections in exoplanet atmospheres are being reported. Here, I present isotopic abundance analyses for three confirmed exoplanet host stars: WASP-77A (prelim.), TYC 8998-760-1 (prelim.), and HIP 29432 (in review). I use MARCS + PHOENIX stellar atmosphere models and TurboSpectrum spectral synthesis code to generate synthetic stellar spectra for line identification and isotopic abundance calculations. Given high resolution and high S/N stellar spectra, we can measure the three main CNO isotope ratios: 12C/13C (Optical [CH], NIR [CO], MIR [CO]), 14N/15N (Optical [CN]), and 16O/18O (NIR, MIR [CO]). These host star isotopic abundances allow for a direct comparison to exoplanet isotope measurements which can trace a planet's formation location relative to volatile "snowlines" and provide insights into an exoplanet's atmospheric composition and evolution.

The Occurrence Rate of Terrestrial Planets Orbiting Nearby Mid-to-late M Dwarfs

David Charbonneau
(Harvard University)

Co-authors: Kristo Ment

We present an analysis of a volume-complete sample of 363 mid-to-late M dwarfs within 15 pc of the Sun with masses between 0.1 and 0.3 $M_\odot$ observed by TESS. We search the TESS 2-minute cadence light curves for transiting planets with orbital periods below 7 days and recover all 6 known planets within the sample as well as a likely planet candidate orbiting LHS 475. Each of these planets is consistent with a terrestrial composition, with planet radii ranging from 0.91 $R_\oplus$ to 1.31 $R_\oplus$. We perform a transit injection and recovery analysis to characterize the sensitivity as a function of planet radius, insolation, and orbital period. We obtain a cumulative occurrence rate of 0.61 terrestrial planets per M dwarf with radii above 0.5 $R_\oplus$ and orbital periods between 0.4-7 days. We find that for comparable insolations, planets larger than 1.5 $R_\oplus$ (sub-Neptunes and water worlds) are significantly less abundant around mid-to-late M dwarfs compared to earlier-type stars, while the occurrence rate of terrestrial planets is comparable to that of more massive M dwarfs. We estimate that overall, terrestrials outnumber sub-Neptunes around mid-to-late M dwarfs at a ratio of 14 to 1, in contrast to GK dwarfs where they are roughly equinumerous. We find evidence for a downturn in occurrence rates for planet radii below 0.9 $R_\oplus$, suggesting that Earth-sized and larger terrestrials may be more common than Mars-sized worlds. We will also summarize work to understand the duration of the active phase of these stars, which indicates that their attendant terrestrial planets experienced very high radiation and particle fluxes for 3 Gyr, sculpting or destroying their secondary atmospheres.

Topic 1 - Detection - Session 3

Topic 1 - Detection - Session 3			
11:00	11:20	00:20	Nuno C. Santos (IA)
			“Looking at the Sun, finding other Earths: the Paranal solar ESPRESSO Telescope”
11:20	11:40	00:20	Baptiste Klein (University of Oxford)
			“Understanding and modelling activity-induced distortions in the absorption lines of Sun-like stars”
11:40	12:00	00:20	Oscar Barragán (University of Oxford)
			"On the Stellar Signal Modelling with Gaussian Process"
12:00	12:20	00:20	Haochuan Yu (University of Oxford)
			“A Gaussian process model for stellar activity in 2D CCF time-series”

Looking at the Sun, finding other Earths: the Paranal solar ESPRESSO Telescope

Nuno C. Santos
(Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto)

Co-authors: the PoET team

High resolution spectroscopy plays a key role in the effort to detect and characterise other Earths. This objective remains, however, challenged by astrophysical noise from the host stars, whose oscillations, granulation, and magnetic activity distort the observed spectra. A new approach to understand this problem is needed.

In this talk I will present PoET, the Paranal Solar Espresso Telescope. Expected to start observations in the end of 2024, PoET will connect to the "planet hunter" ESPRESSO spectrograph (ESO-VLT) and provide both disk resolved and disk integrated ("sun-as-a-star") observations of the Sun. Spectra will be obtained in the ultra-high resolution mode (R>200 000) and cover the full optical domain (380-780 nm) in one single shot.

Using the Sun as a proxy for other solar-type stars, data will allow to map our star and understand in unprecedented detail the contribution of each solar feature to spectral variability that affect the detection and characterisation of exoplanets (precise radial velocities and transmission/emission spectroscopy).

Understanding and modelling activity-induced distortions in the absorption lines of Sun-like stars

Baptiste Klein
(University of Oxford)

Co-authors: Suzanne Aigrain, Oscar Barragan, Hauchuan Yu

Stellar magnetic activity induces both distortions and Doppler-shifts in the absorption line profiles of Sun-like stars. Those produce apparent radial velocity (RV) signals which greatly hamper the search for potentially habitable, Earth-like planets. With the advent of extreme-precision spectrographs, it becomes crucial to develop robust methods to correct for the activity contributions while preserving signatures of planetary origin. In the last few years, innovative methods to exploit the wealth of information present in line profiles rather than just radial velocity time-series have shown promising results.

I will present the results of a thorough investigation of the activity-induced distortions in the solar cross-correlation functions (CCFs), intensively monitored with the high-precision spectrograph HARPS-N. I will review two different activity modelling strategies. In the first one, activity-induced line-shape variations are separated from pure Doppler shifts using a data-driven process. The extracted line-shape temporal variations are then included in a multi-dimensional Gaussian process, allowing us to robustly recover RV signatures as low as 0.4 m/s for planets in the Sun's habitable zone. In the second method, I use an alternative physically-driven approach based on Doppler Imaging to simultaneously reconstruct the distribution of active regions at the surface of the stars and search for planet signatures shifting the line profiles. On the solar data, I will demonstrate that Doppler imaging, initially designed for rapidly-rotating stars, can not only be applied to Sun-like stars, but also give reliable results in term of planet detection. After outlining the two activity mitigation techniques, I will discuss their limitations and potential avenues to overcome them.

On the Stellar Signal Modelling with Gaussian Process

Oscar Barragán
(University of Oxford)

Co-authors: S. Aigrain, B. Klein, H. Yu, N. Zicher, B. Nicholson

Active regions on stellar surfaces induce signals in radial velocity (RV) time series that limit our ability to detect planetary Doppler signals. Gaussian Processes (GPs) have become a popular mathematical framework to model activity-induced RVs given their flexibility to describe stochastic variations. They have been proven successful to detect planetary signals even in extreme cases of stellar activity. In this contribution, we will discuss the state-of-the-art advances and good practices in modelling stellar signals using GPs. Such as data sampling dependence on GP regression, multidimensional GP regression, physical interpretation of GP hyperparameters, among others. We will show some practical examples of how these approaches have been used to detect planet signals in different ranges of stellar activity and their potential future applications.

A Gaussian process model for stellar activity in 2D CCF time-series

Haochuan Yu
(University of Oxford)

Co-authors: Suzanne Aigrain, Baptiste Klein, Oscar Barragán, Annelies Mortier

Activity regions, i.e., spots and faculae, on the rotating stellar disk can distort the shape of the spectral lines, so as to induce variations in the measured radial velocity (RV) time-series. Such activity signals can be roughly two orders of magnitude larger than the signals induced by possible Earth analogues. Efforts to model and mitigate these activity signals have hitherto focused on either the time domain or the velocity domain. In this work, we present a novel approach to model the stellar activity signals directly in the 2D time-series of cross-correlation functions (CCFs) using a Gaussian process (GP). Compared to previous GP models using 1D time-series (e.g., RV, BIS, FWHM), this uses more of the information available in the spectra, and limits the potential degeneracy between the planet and stellar activity signals. Compared to methods which model the line-shape variations without taking the time dimension into account, our approach exploits the time correlation in the variations of the CCF. We tested this method for both synthetic and real datasets down to Signal-To-Noise Ratio (SNR)~100, and showed it can disentangle activity from planet signals even if the periods of the two signals are identical. Furthermore, injection/recovery tests on the HARPS-N solar data show that we can blindly recover planet signals down to <0.2m/s during the high-activity part of the Sun's cycle.

Topic 3 - Dynamics - Session 2

Topic 3 - Dynamics - Session 2			
14:30	15:00	00:30	Susana Barros
			Tidal deformation and tidal decay with CHEOPS
15:00	15:20	00:20	Babatunde Akinsanmi (University of Geneva)
			"The Shape, Orbit and Atmosphere of the Ultra-Hot Jupiter WASP-12b"
15:20	15:40	00:20	Olga Balsalobre Ruza (Center for Astrobiology CAB)
			"Genesis of PDS 70 b Trojans hunted with ALMA"
15:40	16:00	00:20	Omar Attia (University of Geneva)
			"The spin-orbit angle distribution of close-in exoplanets under the lens of tides"

Tidal deformation and tidal decay with CHEOPS

Susana Barros
(Instituto de Astrofísica e Ciências do Espaço)

Tidal forces between short-period planets and their host stars are extreme. These lead to the deformation of the planet and the shrinkage of the planet’s orbit. Using the new ESA mission CHEOPS we are attempting to measure both these effects for a sample of exoplanets. Measuring the tidal deformation of the planet would allow us to estimate the second degree fluid Love number and gain insight into the planet's internal structure. Measuring the tidal decay timescale would allow us to estimate the stellar tidal quality factor, which is key to constraining stellar physics. WASP-103 was our first target since it had the largest estimated signature of the tidal deformation. I will present the first detection of the tidal deformation of a planet directly from its light curve. This allowed us to measure the Love number of WASP-103b. I will also present our measurements of the tidal decay of a few targets including WASP-103b and explore our future perspectives.

The Shape, Orbit and Atmosphere of the Ultra-Hot Jupiter WASP-12b

Babatunde Akinsanmi
(University of Geneva)

Co-authors: Monika Lendl, Susana Barros

Ultra-hot Jupiters (UHJs) orbit very close to their host stars and are subjected to strong stellar tidal forces and irradiation. The strong tidal interaction leads to the deformation of the planet from the usual spherical shape. As the response of a planet to tidal forces depends on its interior structure, detecting tidal deformation provides insight into the interior structure of a planet through measurement of the second fluid Love number. Furthermore, tidal interaction can lead to the decay of the planetary orbit as the planet loses orbital momentum to the star. Measuring the tidal decay rate and timescale allows us to estimate the stellar tidal quality factor which quantifies the efficiency of tidal dissipation within the star. The intense irradiation received by UHJs also results in atmospheres that significantly differ from those of the Solar System gas giants, and are predicted to show temporal variability in their emissions. Phase-curve observations of UHJs provide an excellent opportunity to study these phenomena to gain a better understanding of these extreme planets.

We present the characterization of the peculiar UHJ, WASP-12b, combining phase curve observations from TESS and CHEOPS space telescopes. WASP-12b has a short orbital period of 1.09 around a star of 6300K which makes it stand out as a prime target to study the extreme conditions on UHJs. The result of our analysis shows that the planet is tidally deformed along the axis pointing towards the star and we measure its Love number. This makes WASP-12b the second exoplanet, after WASP-103b, for which tidal deformation has been robustly detected, and both detections have been facilitated by CHEOPS observations. By measuring the transit times with CHEOPS, we refine the orbital decay rate by 12% and also the stellar tidal quality factor. From the phase curve observations, we measure the atmospheric brightness of the planet as a function of phase, constraining the dayside and nightside fluxes, and also the hotspot offset in these visible passbands. By modeling the thermal emission spectrum of the planet, we measure the geometric albedo of the planet in the CHEOPS and TESS passbands. We also probe for variability in the dayside atmospheric brightness of the planet on different timescales by comparing CHEOPS eclipse depth measurements taken over 3 years of observations.

Genesis of PDS 70 b Trojans hunted with ALMA

Olga Balsalobre Ruza
(Center for Astrobiology-CAB, CSIC-INTA)

Co-authors: Itziar De Gregorio, Jorge Lillo-Box, Nuria Huélamo, Álvaro Ribas

Dust is key to find planets during the first million of years of stars life. The planet-star interactions imprint signatures in the protoplanetary disk that serve as hints to locate them. Some of those substructures are rings, gaps or elliptical arms, and they have been recently observed in tens of disks with high angular resolution ALMA images. As predicted by hydrodynamical simulations, one of the most common signatures that evidence the presence of forming planets is dust in co-rotation trapped in the Lagrangian points of the protoplanets. In this talk, we will present the first tentative detection of co-orbital dust trapped within the orbit of a confirmed protoplanet: a mass up to 0.7 masses of the Moon of mm-sized dust particles accumulated in the Lagrangian point L5 of the iconic planet PDS 70 b. We will outline how future observations will confirm or reject its co-orbital nature, and how such a discovery can contribute to understand planetary formation and evolution processes. If confirmed, this would be the first direct evidence of the nursery of Trojan bodies supporting their formation theories and opening the window to their detection in mature systems.

The spin-orbit angle distribution of close-in exoplanets under the lens of tides

Omar Attia
(University of Geneva)

Co-authors: V. Bourrier

The spin-orbit angle is a powerful observational marker that can be used to unveil past dynamical histories. For the first time, we analyze a sample of nearly 200 true spin-orbit angles and study it in a broad statistical context, connecting it to the intensity of tidal interactions between close-in planets and their host stars. Our comprehensive statistical analysis corroborates the strong link between close-in orbital architectures and tidal effects, and further highlights that planets bordering the hot Neptunes desert are particularly affected by disruptive dynamical processes misaligning their orbits. Additional observational and theoretical efforts on these exciting regions of the parameter space will be pivotal to shed light on the possible history of the planets populating them.

Topic 3 - Dynamics - Session 3

Topic 3 - Dynamics - Session 3			
16:30	17:00	00:30	Alexander Mustill
			The evolution of planetary systems through time
17:00	17:20	00:20	Leon Ka-Wang, Kwok (Geneva Observatory)
			"Can the stellar dynamical tide destabilize the resonant chains of planets formed in the disk?"
17:20	17:40	00:20	Aurélie Astoul (University of Leeds)
			"Do non-linear effects disrupt tidal dissipation estimates in the convective envelopes of compact star-planet systems?"

The evolution of planetary systems through time

Alexander Mustill
(Lund University)

Planetary systems do not remain unchanged with time: they are expected to undergo a variety of processes, such as dynamical planet--planet interactions, and tidal interaction with the host star, that can lead to gentle or radical changes to the planets' orbits. Particularly significant changes occur when their host star leaves the main sequence and ascends the red giant branch, followed by the asymptotic giant branch and the transition to a white dwarf. The large increase to the stellar radius (by a factor ~100) can result in the engulfment of close-in planets, a process enhanced by the strengthening tidal forces as the stellar radius expands. The increase in stellar luminosity (by a factor of thousands) heats surviving close-in planets, and greatly enhances radiation forces acting on small bodies, such as Poynting–Robertson drag and the Yarkovsky effect, as well as the YORP torque that affects their spin state. Finally, the decrease in stellar mass (by a factor of a few) causes the outward expansion of the orbits of planets and asteroids, as well as increasing the mass ratio of the planets to the star and strengthening planet--planet interactions. I will discuss these phenomena with a focus on the effects of changes to the host star on the planetary system.

Can the stellar dynamical tide destabilize the resonant chains of planets formed in the disk?

Leon Ka-Wang, KWOK
(Geneva Observatory)

Co-authors: Emeline Bolmont, Alexandre Revol, Stéphane Mathis, Aurélie Astoul, Corinne Charbonnel, Sean Raymond

Resonance chains of planets are a common outcome of planetary formation and evolution in the protoplanetary disks. However, from observations, resonant chains are rare (a famous example would be the TRAPPIST-1 system). This implies that most of these chains are destabilized after the end of the disk phase (Izidoro et al. 2017). In stellar convective regions, tidal dissipation consists of two components, first one is the equilibrium tide, a large-scale circulation to recover the hydrostatic equilibrium due to the presence of the companion (Zahn, 1966). The second one is the dynamical tide, which is the inertial waves driven by the Coriolis acceleration (Ogilvie & Lin, 2007). Stellar tide, particularly the dynamical tide, could contribute to the destabilization of the resonance chains. Due to the resonant nature of the dynamical tide, the tidal excitation frequency could correspond to a resonant frequency of the star, implying that the inner planet could experience a migration boost, disrupting the resonant chains' fragile stability.

However, some previous studies suggest that one of the famous tidal models, the constant angular lag model, is mathematically contradictory (Efroimsky & Makarov 2013) and that the constant time lag model predicts the pseudo-synchronization for terrestrial objects (Makarov & Efroimsky 2013) which is not observed. Furthermore, these models assume a specific & simple frequency dependence, hence they can not account for the complex multiple frequencies dependence. This is particularly important for eccentric objects, as the multiple frequencies dependence can not be ignored. This suggests that we need a better tidal model for better descriptions.

We present the results of our investigation on the influence of the stellar dynamical tide on the stability of the resonant chains using the Kaula model (Kaula, 1961) which accounts for the more complex dependency of the dynamical tide. We use the N-body code Posidonius (Blanco-Cuaresma & Bolmont, 2017) where we have implemented the Kaula model and the dynamical tide. The love number spectra are computed with the code used in Astoul & Barker (2021). We performed simulations of the evolution of the resonant chains and studied their stability with initial conditions for multi-planet systems (multi-super-Earth) from Izidoro et al. (2021). We consider both a population of resonant chains and non-resonant chains which are the outcome of their formation models. We tested these initial conditions without tidal effect first to reproduce the dynamics of the resonant chains. We then applied the tidal forces to see whether the dynamical tide would be able to destabilize the resonant chains. We also applied our model to hypothetical systems of massive planet(s).

Our work provides insight into whether the dynamical tide is the corresponding physical mechanism to destabilize the resonant chains, and provides the exoplanet community an N-body code with the dynamical tide & Kaula model for further studies in tidal effects for close-in planets/ binary systems.

Do non-linear effects disrupt tidal dissipation estimates in the convective envelopes of compact star-planet systems?

Aurélie Astoul
(University of Leeds)

In close star-planet systems, tidal interactions are known to shape the orbital architecture of the system, and modify the star and planet spins. Most stars around which planets have been discovered are low-mass stars and thus feature a (differentially-rotating) convective envelope, as is also expected in giant gaseous planets like Hot-Jupiter. The dissipation of tidal flows, and more specifically the dissipation of inertial waves (restored by the Coriolis acceleration, and recently observed in the Sun) is of particular importance in the convective envelopes. This is particularly true in the early stages of the life of the compact system. In parallel, the non-linear self-interaction of inertial waves can affect the rotation of the body in which they propagate. Indeed, they can trigger differential rotation in convective shells in the form of axisymmetric zonal flows, as shown in numerical and experimental hydrodynamical simulations. In turn, the propagation and dissipation of inertial waves are also modified by differential rotation, as well as the angular momentum transfers in the system. From the observational side, important efforts (started with Kepler and now with TESS data analysis) have been undertaken to constrain possible orbital decay of really close planets like Hot-Jupiter. In that sense, the (non-linear) dissipation of tidal waves is one promising avenue to explain inward migration of the planet toward its host star. In this context, I will present my recent results of hydrodynamical direct numerical simulations of tidally-forced inertial waves, in 3D spherical convective shells. In these non-linear simulations, the onset of tidally-driven zonal flows, along with wave/zonal flow interactions, can deeply modify tidal dissipation rates from prior linear predictions. All permissible forcing frequencies for inertial waves have been explored, along with different kinematic viscosities, various tidal amplitudes, and size of the convective shells which are representative of the diversity of convective envelopes of low-mass stars and giant gaseous planets. We show that the finer the convective envelope and the lower the viscosity, the more non-linear effects disrupt linear estimates of tidal dissipation. When important, non-linear effects and especially differential rotation, have a tendency to flatten out the (peaky) highly-frequency dependent tidal dissipation spectrum. Overall, it results in lowering the frequency-averaged tidal dissipation rates. The new estimates for tidal dissipation are of particular interest for close giant planets which are not yet circularised or synchronised, in which tidal inertial waves can be excited and subsequently damped.

Topic 2 - Populations - Session 5

Topic 2 - Populations - Session 5			
09:20	09:50	00:30	Gijs Mulders The demographics of exoplanets and its dependence on host star type
09:50	10:10	00:20	Serena Benatti (INAF-OAPa) “Understanding the evolution of planetary systems with GAPS”
10:10	10:30	00:20	Ignasi Ribas (ICE-CSIC) “The CARMENES search for exoplanets around M dwarfs: exoplanet discoveries and insights into stellar astrophysics”

The demographics of exoplanets and its dependence on host star type

Gijs Mulders
(Universidad Adolfo Ibañez, Chile)

Exoplanets are a diverse population. The more than 5000 known exoplanets different greatly in their masses, sizes, orbital periods, and even the type of stars they orbit. There is, however, also order in this chaos, with certain type of planets and planetary systems occurring more frequently than others. By correcting for the biases inherent to different exoplanet detection methods, the demographics of planets orbiting other stars can be constructed.

In this talk I will focus on the stellar mass dependence of the two main populations of exoplanets: the (ice) giant planets that extends over orders of magnitude in star-planet separation and are detected by radial velocity, micro-lensing, direct imaging, and transit surveys. And the population of sub-Neptunes that orbit close to their host stars and are mainly observed by transit and radial velocity surveys.

The giant planet occurrence scales positively with stellar mass, consistent with theories of core accretion and measured protoplanteray disk masses. Sub-Neptunes, on the other hand, occur more frequently around M dwarfs than they do around sun-like stars. I will discuss the possible origins of this trend and new observational evidence indicating this trend brakes down at the lowest mass stars.

Understanding the evolution of planetary systems with GAPS

Serena Benatti
(INAF - Astronomical Observatory of Palermo)

Co-authors: S. Desidera & the GAPS Young Objects Team

The Global Architecture of Planetary Systems (GAPS) project, gathers a large part of the Italian community working on exoplanets by using the high resolution spectrographs mounted at the TNG. In particular, the Young Objects sub-program aims to investigate the origin of the observed diversity of the planetary systems by observing them at young ages (up to a few hundreds of Myr), when planets are closer to their formation time and possibly to their birth-sites, and the formation and evolution processes are still at play. The main difficulty in this kind of study is the high level of stellar activity of the host stars, able to mask planet-induced signals in radial velocity time series. For a proper treatment of the high level of the stellar activity, typical for these objects, we work to improve the RV extraction and exploit the Gaussian process regression modelling, supported by an intensive RV monitoring.

I will review the main results of this ongoing survey, including the confirmation and the retraction of known planet candidates, the contribution in the evaluation of the frequency rate of planets around young stars, and the characterisation of young transiting planets with the measurement of their mass. The determination of the stellar properties such as the age and membership to groups, and chemical composition is also a fundamental part of our work, as well as simulations of the planetary atmosphere photo-evaporation and the dynamical scenarios of the systems.

All these studies contribute to unveil the still poorly known scenario of the formation and evolution of young close-in planets.

The CARMENES search for exoplanets around M dwarfs: exoplanet discoveries and insights into stellar astrophysics

Ignasi Ribas
(Institute of Space Sciences (ICE, CSIC) & IEEC)

Co-authors: On behalf of the CARMENES Consortium

The CARMENES instrument, mounted on the 3.5-m telescope of the Calar Alto observatory in Almería, Spain, was conceived to deliver high-accuracy radial velocity (RV) measurements with long-term stability to search for temperate rocky planets around a sample of nearby stars. Besides, the broad wavelength coverage could provide a range of stellar activity indicators to assess the nature of potential RV signals and also valuable spectral information to characterise the stellar targets. The CARMENES survey has been running since 2016 and has collected over 20,000 spectra leading to precise RVs for 360 targets. Target selection was aimed at minimising biases and nearly 50% of all known M dwarfs within 10 pc are included. CARMENES data have proven very successful in identifying and measuring planetary companions. And we have also shown them to be useful for a variety of additional applications such as the determination of stellar fundamental and atmospheric properties, the characterisation of stellar activity and the study of exoplanet atmospheres, among many others. In this contribution we will present the CARMENES data and the statistical properties of the sample and the spectroscopic measurements, as well as a contextual view of the exoplanet population revealed by the survey.

Topic 1 - Atmospheres - Session 5

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11:00	11:30	00:30	Aline Vidotto
			The influence of stellar winds/outflows on atmospheres and their observations
11:30	11:50	00:20	David Wilson (University of Colorado)
			“The ultraviolet and X-ray behaviour of TRAPPIST-1”
11:50	12:10	00:20	Marina Lafarga Magro (University of Warwick)
			“The hot Neptune WASP-166 b with ESPRESSO: A tentative blue-shifted water signal constrains the presence of clouds”
12:10	12:30	00:20	Eduardo Alexandre de Sousa Cristo (IA)
			“Unveiling the HD 189733 system with ESPRESSO”

The impact of stellar activity and winds on the evolution of planets

Aline Vidotto
(Leiden Observatory, Netherlands)

Stellar activity can reveal itself in the form of radiation (eg, enhanced X-ray coronal emission, flares) and particles (eg, winds, coronal mass ejections). Together, these phenomena shape the space weather around (exo)planets. Because most of the known exoplanets have significantly closer orbital distances than solar system planets, they are often embedded in much harsher particle and radiation environments, leading to stronger interactions between the exoplanet and its surrounding environment. In this talk I will present an overview of how stellar activity and winds can induce and shape atmospheric escape in exoplanets. I will focus mostly on close-in gas giant planets, whose escaping atmospheres are somewhat easier to observe. I will then discuss how the observability of atmospheric escape, through spectroscopic transits, evolve on billions of years timescales.

The ultraviolet and X-ray behaviour of TRAPPIST-1

David Wilson
(University of Colorado)

Co-authors: Cynthia Froning, Kevin France, Girish Divvuri, Allison Youngblood, Christian Schneider and the Mega-MUSCLES Collaboration

The seven Earth/Venus sized planets of the TRAPPIST-1 system are arguably the most important targets for current exoplanet science, being the most amenable potentially habitable planets for atmospheric characterization in the near future. Reliably assessing the atmospheric composition, structure, and even existence of the atmospheres of the TRAPPIST-1 planets requires a comprehensive understanding of the input they receive from the central star, and in particular the ultraviolet and X-ray flux. The relative intensity of different regions of the ultraviolet governs atmospheric photochemistry, whilst the X-ray and extreme ultraviolet flux can drive hydrodynamic escape leading to atmospheric mass loss.

In this presentation I will describe our ongoing efforts to characterize the high-energy emission of TRAPPIST-1 as a function of both wavelength and time. As part of the Mega-MUSCLES survey, we have assembled a panchromatic spectral energy distribution (SED) of TRAPPIST-1. The SED combines data from the Hubble and XMM-Newton space telescopes at ultraviolet and X-ray wavelengths with state-of-the-art Differential Emission Measure models in the currently unobservable extreme ultraviolet. I will discuss the methods used to produce the SED, including its strengths and limitations, as well as how to access the data. Several papers have already made use of the SED to model the TRAPPIST-1 planets, and I will provide an overview of the major science results and consequences for upcoming JWST observations.

In addition to the SED, we are also exploring how the ultraviolet behavior of TRAPPIST-1 changes over time. I will present first results from our ultraviolet photometric monitoring campaign, which will be taking data in the weeks leading up to the conference. This campaign will provide the first assessment of the ultraviolet variability of TRAPPIST-1 over time, as well as dramatically improving the near-ultraviolet regions of the SED.

The hot Neptune WASP-166 b with ESPRESSO: A tentative blue-shifted water signal constrains the presence of clouds

Marina Lafarga Magro
(University of Warwick)

Co-authors: I. Ribas, M. Zechmeister, A. Reiners, Á. López-Gallifa, D. Montes, A. Quirrenbach, P. J. Amado, J. A. Caballero, M. Azzaro, V. J. S. Béjar, A. P. Hatzes, Th. Henning, S. V. Jeffers, A. Kaminski, M. Kürster, P. Schöfer, A. Schweitzer, H. M. Tabernero, M. R. Zapatero Osorio

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 these can provide insight to their planetary formation and evolution, and shed light on the origin of the desert. Here, we assess the presence of water in one such planet, 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, WASP-166 b 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 the Earth's telluric absorption via principal component analysis, which is crucial to the search for water in exoplanets. We use a cross-correlation-to-likelihood mapping 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. We tentatively detect a water signal blue-shifted about 5 km/s from the planetary rest frame. This is the first time water has potentially been observed in the optical with ESPRESSO. Injection and retrieval of model spectra show that a solar-composition, cloud-free atmosphere would be detected at 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, scheduled to be observed in the near-infrared with JWST, which will provide further constraints on the presence of molecules such as water.

Unveiling the HD 189733 system with ESPRESSO

Eduardo Alexandre de Sousa Cristo
(Instituto de Astrofísica e Ciências do Espaço)

Co-authors: Nuno Santos and Olivier Demangeon

The ESPRESSO (Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations) is a high-resolution spectrograph mounted on the Very Large Telescope (VLT) in Chile. It is a powerful tool for detecting and characterizing exoplanets, as it allows astronomers to study the spectra of host stars and their planets with high accuracy.

In this study, the chromatic Rossiter-McLaughlin (CRM) technique was used to analyze the broadband transmission spectrum of HD 189733b with ESPRESSO. The CRM effect occurs when a planet with an atmosphere transits in front of its host star, causing an additional distortion to the classical RM effect in the shape of the star's spectral lines. The distortion caused by the atmosphere, which absorbs or scatters certain wavelengths of light, is seen as an apparent change in the planet's radius.

The improved Rossiter-McLaughlin model used in this study includes the effects of the rotation velocity of the stellar surface and the convective blueshift, which can impact the accuracy of RM modeling. By splitting the wavelength range of ESPRESSO into smaller bins, we were able to compute the planetary radius as a function of wavelength and derive the transmission spectrum.

The resulting transmission spectrum shows decreasing radii as a function of increasing wavelength, which is often associated with the presence of haze in the atmosphere of exoplanets. This finding can provide valuable insights into the composition and structure of the atmosphere of HD 189733b, and can help us better understand the diverse nature of exoplanets in general.

Topic 1 - Detection - Session 4

Topic 1 - Detection - Session 4			
14:30	15:00	00:30	Sophia Sulis
			Characterizing transiting planets in the presence of stellar noise
15:00	15:20	00:20	Giacomo Mantovan (University of Padova)
			“The youngest compact multi-planet system with an inner sub-Neptune and an outer warm-Saturn”
15:20	15:40	00:20	Nuno Miguel Rosário (IA)
			“Constraining the structure and composition of two short-period rocky planets spanning the radius valley”
15:40	16:00	00:20	Hugh Osborn (University of Bern)
			“Planetary hide & seek: Confirming TESS’s hidden long-period planets using CHEOPS”
16:00	16:20	00:20	Neda HEIDARI (IAP)
			“HD88986: a multi-planet system with a temperate transiting sub-Neptune and a wide-orbit Jupiter mass planet”

Characterizing transiting planets in the presence of stellar noise

Sophia Sulis
(Laboratoire d'astrophysique de Marseille-LAM)

In this talk, I will focus on the impact of stellar activity on the characterization (mass, radius) of transiting exoplanets based on photometry and ground-based radial velocity follow-up.

In the context of the future PLATO space mission (to be launched in 2026), the objectives in terms of radius and mass precision are 5% and 10%, respectively. I will discuss the impact of identified noise sources on these error budgets for terrestrial-type planets, which are the main objective of the PLATO mission. I will then open the discussion on new observing strategies to characterize the signatures of stellar activity and mitigate them for the study of planets.

The youngest compact multi-planet system with an inner sub-Neptune and an outer warm-Saturn

Giacomo Mantovan
(University of Padova)

Co-authors: Luca Malavolta, Silvano Desidera, Serena Benatti, Giampaolo Piotto, GAPS team, TFOP team

Short-period giant planets (P $\lesssim$ 10 days) are frequently found to be lonely compared to other classes of exoplanets. Small companions on inner orbits are present only in four compact systems (P $\lesssim$ 15 days) with giants: WASP-47, Kepler-730, TOI-1130, and TOI-2000.

Among these unique systems, I present the confirmation of the youngest multi-planet system composed of an inner sub-Neptune and an outer warm-Saturn orbiting a moderately young (~700 Myr) G-type star revealed by TESS observations.

With the help of multidimensional Gaussian processes, I modelled at once stellar activity and planetary signals from unpublished HARPS-N radial velocity time series. Given my modelling and excellent estimation of stellar parameters, I clearly detected the warm-Saturn and marginally detected the sub-Neptune.

The system’s rare architecture and moderately young age make it particularly promising for measuring the obliquity between the orbital plane of the giant and the spin axis of the star, which is a key diagnostic for the formation path of the planetary system. First, we can access the original configuration when observing systems young enough to have avoided tidal alterations of the obliquity. Then, unlike ordinary short-period giants, we can rule out the high-eccentricity migration scenario for compact systems such as my target and test the other formation models through detailed atmospheric characterization. With a Transmission Spectroscopy Metric over 300, the warm-Saturn becomes the most amenable warm giant ($10 < P < 100$ days) for JWST atmospheric characterisation, outdoing all known similar planets.

Constraining the structure and composition of two short-period rocky planets spanning the radius valley

Nuno Miguel Rosário
(Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto)

Co-authors: CHEOPS Team and KESPRINT Team

The CHaracterising ExOPlanet Satellite (CHEOPS) is a follow-up mission aiming at the precise characterisation of exoplanetary systems. This system was observed by the Transiting Exoplanet Survey Satellite (TESS) and two short-period planets were found orbiting a K1 dwarf star (V=9), lying on opposite sides of the radius valley and therefore providing an excellent laboratory for formation and evolution theories as well as internal composition and atmospheric evaporation studies.

We obtained 6 visits with CHEOPS and 32 additional radial velocity (RV) measurements from the High Accuracy Radial Velocity Planet Searcher (HARPS) with the goal of constraining the internal structure and composition of both planets and enabling future atmospheric studies. We also included 48 available RV measurements from the Planet Finder Spectrograph (PFS).

In this work, we reanalyse the TESS light curves by isolating the transits and normalising the individual light curves to minimise long-term stellar activity. We then perform a joint fit of the TESS and CHEOPS light curves together with available RV data from HARPS and PFS. We simultaneously fitted the planetary signals, the stellar activity signal and the instrumental decorrelation model (in particular for the CHEOPS data) and derived the internal structure of both planets using a Bayesian retrieval code. The stellar activity signal was modelled using a Gaussian process with the logRhk indicator.

With radius and mass measured with a precision higher than 2% and 6% respectively, planet b is amongst the most precisely characterised exoplanets. Planet c also shows a high precision in radius, being higher than 3%. From our results, we conclude that both planets have a small iron core with a mass fraction lower than 15%. Planet b is predominately rocky with a thin water layer, demonstrating that not all planets below the radius valley are completely dry. Planet c has a more significant layer of water and also a gas envelope with M_gas=0.03 M_Earth.

Our analysis using new data from TESS, CHEOPS, HARPS and PFS allows for a better constrain not only on the planetary and transit parameters, but also on the internal structure and composition, which provides a basis for future atmospheric studies that may add further clues about atmospheric evolution.

Planetary hide & seek: Confirming TESS's hidden long-period planets using CHEOPS

Hugh Osborn
(University of Bern)

TESS has provided hundreds of small planets orbiting bright stars for which JWST can now provide atmospheric characterisation. However, the vast majority of planets with orbital periods longer than ~20d have evaded discovery in TESS due to its 27-day noncontinuous survey strategy. Such planets are scientifically interesting, as they maintain more primordial orbits and atmospheres than their hot, evaporated & tidally-locked cousins. CHEOPS is a 30cm space telescope focussed on the targeted characterisation of transiting exoplanets around bright stars. I will show how we have successfully used CHEOPS to confirm planets in this long-period regime. The first step was to identify so-called "duotransits" found by TESS - missed planet candidates with transits separated by a large observational gap (often 2 years). We then used a custom bayesian transit model and precisely determined stellar parameters to compute probabilities for each period alias, allowing us to prioritise certain transits for CHEOPS observations. This began a game of hide-and-seek, where CHEOPS searched through most likely periods until finding a planetary transit and confirming the orbit. The project has resulted in 20 new planets, with an average radius less than 3 earth radii, an average orbital period of 31 days, and an average G-band magnitude of 9.2. Hence we have enormously expanded the population of warm characterisable mini-Neptunes. This sample includes the brightest system of 6 transiting planets ever found, a Neptune orbiting a naked-eye star, as well as numerous planets in bright multiplanet systems.

HD88986: a multi-planet system with a temperate transiting sub-Neptune and a wide-orbit Jupiter mass planet

Neda HEIDARI
(Institut d'Astrophysique de Paris, IAP)

Co-authors: I. Boisse, SOPHIE team and et al.

Transiting planets with orbital periods longer than 40 days are extremely rare among the 5000+ discovered planets. Consequently, the lack of these populations poses a challenge to research into planetary demographics, formation, and evolution, as well as the star-planet relationship. In this talk, we propose the discovery and characterization of HD88986 b, a transiting sub-Neptune planet with one of the longest orbital periods, and its Jupiter-like companion. To validate this discovery, we used a combination of more than 25 years of extensive radial velocity measurements (440 SOPHIE data, 31 ELODIE data, 34 HIRES data), Gaia DR3 data, 21-year photometric observation of an automatic photoelectric telescope (APT), 2 sectors of TESS data, and a 7-day observation of CHEOPS. Our analysis shows that the sub-Neptune planet has a radius of $2.360^{+0.10}_{-0.099}$ R_E and a mass of $19.4^{+2.7}_{-2.6}$ M_E, and it orbits every $146.4^{+0.05}_{-0.05}$ days around one of the nearest and brightest stars, HD88986 (G2V type, Gmag=6.30, distance= 30 pc). The second planet, using Gaia DR3 excess noise, is compatible with an edge-on configuration, and the probability that HD88986 c is a planet with a mass smaller than 13.5 Mjup is ~ 94%. The discovery of HD88986 b and its Jupiter-like companion, whose configuration has some similarities with that of our own solar system, will have a significant impact on our understanding of the puzzle of planetary formation and evolution, as well as planetary habitability. The temperate nature of HD88986 b ($T_{eff}= 476^{+13}_{-10}$), thanks to its long orbital period, will open up exciting opportunities for future studies of internal structure and atmosphere characterization.