EXOCLIMES POSTER ABSTRACT GUIDE
SESSION 2

Saugata Barat: Tracing the late formation and early evolution of young Sub-Neptunes progenitors Sub-Neptunes and super-Earths correspond to the most common population exoplanets, yet there are several burning questions regarding their formation and their early evolution. In this context the 23 Myr old V1298 Tau system, composed of three Neptunes/Sub-Neptunes transiting exoplanets, represents a unique opportunity to probe the early conditions of what are most likely super-Earth/sub-Neptune progenitors. We present observational campaigns dedicated to probe the atmospheres of the V1298 Tau planets to trace fossil records of their formation, though the determination of their mass, their elemental abundances, intrinsic temperature, and ongoing evolution though their atmospheric dynamics and escape. We find that the planets in this system have lower masses and much lower metal abundances than initially thought, and that atmospheric escape is occurring at lower rates than expected. Our puzzling findings challenges planet formation paradigms for small planets and we discuss our results in the context of planet formation, comparative exoplanetology with other young and mature systems, as well as within the same system.

Michael Battalio: Annular modes set climate variability across the solar system and beyond Zonal-mean climate variability captures a large percentage of the circulation variability for Earth, Mars, and Titan. We have shown that Terran and Martian reanalyses and the Titan Atmospheric Model indicate zonal-mean variability—called annular modes—as extremely important across the solar system. Two types of modes operate on all three worlds: baroclinic annular modes emerging from the zonal-mean eddy kinetic energy (EKE-AM) that describe pulsation of the storm track, and barotropic modes diagnosed from the zonal-mean zonal wind (U-AM). Mars's and Earth's U-AMs represent north-south shifts of the jet stream, and Titan's U-AM describes vertical jet shifts. Annular modes exhibit characteristic timescales dependent on planetary parameters. The EKE-AM varies O(10) days, and the U-AM varies O(100) days. This variability could impact exoplanet observations if annular modes have sufficient amplitude.

Katherine Bennett: A Tale of Data Reductions: The JWST Transmission Spectrum of the Warm Super-Earth GJ 1132b With the launch of JWST, the door to the characterization of rocky exoplanets and (ultimately) the search for life has opened. As the smallest and coolest stars, M-dwarfs are host to compact systems that are the most amenable to characterization. This has driven the exoplanet community to focus on the "M-dwarf opportunity", but the question of whether exoplanet atmospheres can endure in the close-in, high-energy environment of M-dwarf stars remains almost entirely unknown. The search for the dividing line between rocky exoplanets with atmospheres and those without has been christened the "cosmic shoreline". The JWST Cycle 1 GO program 1981 plans to shed light on this shoreline for M-dwarf systems by using transmission spectroscopy to probe five nearby rocky exoplanets. In this poster, we report on our results for GJ 1132b, a warm (585 K) 1.13 Earth-radii planet orbiting an M-dwarf in a 1.63-day orbit. We observed two transits of GJ 1132b with JWST/NIRSpec's G395H mode, and we show the transmission spectrum between 2.9–5.3 µm. We discuss the data reduction challenges and emphasize the importance of utilizing multiple visits and reduction pipelines before interpreting the data. We compare our preliminary results with those from other planets in this program, LHS 475b and GJ 486b, in order to understand the complexity of constraining the cosmic shoreline in M-dwarf systems.

Siddharth Bhatnagar: Reconsidering the habitability of planets in the light of climate multistability Under the same external forcing, a planet can exist in multiple alternative stable states (Strogatz 2018) due to several feedbacks (e.g., ice-albedo feedback). This "climate multistability" has implications for habitability as planets can "tip" from a habitable to an uninhabitable state (or vice-versa), at a critical "tipping point." At Exoclimes, I will present our investigations of the implications of climate multistability on habitability and the habitable zone (Kasting et al. 1993), using a 1-D Energy Balance Model (EBM;

Spiegel et al. 2008) and a 3-D Global Climate Model (GCM), LMD's Generic Planetary Climate Model (Generic PCM; Hourdin et al. 2006). With our EBM, we found three stable states for an Earth-like planet at 1.00 AU from a Sun-like star: (a) Snowball (204 K), (b) Temperate (290 K) and (c) Runaway (888 K). However, previous works (e.g., Brunetti et al. 2019) have shown that the oceanic description also affects the number of steady states. Therefore, I will also present our newly developed dynamical ocean model of the Generic-PCM (improved sea-ice evolution, ocean dynamics, parallelisable), with a focus on the differences that it brings. Finally, I will compare the outcomes of the final climate states between the EBM and GCM.

Marrick Braam: Stratospheric dayside-to-nightside circulation responsible for nightside ozone hotspots on tidally-locked exoplanets Interpreting atmospheric spectra of exoplanets requires understanding the underlying atmospheric physics and chemistry. Studies have previously shown that for tidally locked, Earth-like exoplanets that orbit M-dwarf stars, photochemistry supports a highly structured 3-D ozone distribution, including a stratospheric ozone layer. We use a 3-D coupled Climate-Chemistry model (CCM), the Met Office Unified Model with the UK Chemistry and Aerosol framework, to describe the atmosphere of Proxima Centauri b. The chemical network includes the Chapman ozone reactions and the hydrogen oxide and nitrogen oxide catalytic cycles. We find that ozone is mainly produced on the dayside of the planet, initiated by the incoming stellar radiation. The ozone is then advected to the nightside, where it descends at the locations of permanent Rossby gyres that result in localised ozone hotspots. I will show that a stratospheric dayside-to-nightside overturning circulation results in exchange between the stratosphere and troposphere and drives this nightside ozone distribution. This finding illustrates the 3-D nature of exoplanetary atmospheres and the potential impact on spectroscopic observations.

Angela Burke: Abiotic Oxygen Production in High-Obliquity and High-Eccentricity Planet Atmospheres Oxygen is widely considered to be a reliable biosignature in the search for life elsewhere. However, several mechanisms create abiotic oxygen, or oxygen from non-biogenic sources. These mechanisms must be thoroughly characterized to rule out false positive identifications of life in the future. Previous experiments from 1-D planetary evolution models have predicted significant abiotic oxygen accumulation resulting from a variety of initial volatile inventories, but the production of abiotic oxygen from atmospheric water loss did not consider the effect of planetary obliquity or eccentricity. 3-D Global Climate Models (GCMs) have shown that stratospheric humidity increases on planets with higher degrees of obliquity through enhanced seasonality, which should result in significant levels of atmospheric water loss. However, neither the minimum obliquity necessary to trigger significant stratospheric humidity accumulation nor the effect of orbital eccentricity have been studied. We address this unknown obliquity parameter by using the ExoPlaSim GCM to quantify stratospheric humidity for a range of obliquity, eccentricity, insolation, and CO_2 levels. We then develop a parameterization for the 3-D stratospheric humidity concentration that can be used in long-term 1-D planetary evolution models to study the effect of higher degrees of obliquity and eccentricity on atmospheric water loss.

Ludmila Carone: The risk of rocky planets around red dwarfs to become Exo-Venuses – VPLANET/MagmOc V2.0 Multi-Outgas VPLANET MagmOc is a versatile magma ocean model with erosion of water vapour in the open source VPLANET framework. V1.0 with pure H_2O outgassing was presented, benchmarked with Solar System planets and applied to the potentially habitable rocky planets around TRAPPIST-1. We present here a major improvement of this model that includes now a) thermal emission calculated with a full radiative transfer code and b) simultaneous outgasing of H_2O and CO_2 informed by planet formation models.

We derived evolution tracks of an outgassed mixed H_2O/CO_2 atmosphere on several rocky planets around red dwarf stars: TRAPPIST-1e, f and g, LP890-9c , and LHS 475b.We find that all rocky planets around red dwarfs, in particular TRAPPIST-1 g, run the risk to evolve into Exo-Venuses with thick CO_2 atmospheres after the magma ocean stage. In particular, volatile-rich composition with more than 10%wt H_2O initally would make it very difficult to build up a habitable atmosphere on rocky planets around M dwarf stars. In any case, the amount of remaining oxygen in the atmosphere can be used to determine a lower limit for the initial H2O content and thus its formation scenario.

Collin Cherubim: IsoFATE: Modeling Isotopic Fractionation via Atmospheric Escape to Infer Atmosphere Evolution Pathways Measurements of planet radius and atmospheric isotopic fractionation offer a means to probe atmospheric evolution and to better constrain competing formation mechanisms. We are developing a numerical model called IsoFATE that computes fractionation via thermally-driven escape mechanisms. Our current analysis focuses on deuterium/hydrogen and helium/hydrogen enhancement. Incorporating diffusive fractionation and time-varying mass-radius relations derived from thermal evolution models, our results suggest that deuterium/hydrogen enhancement is primarily a function of total planetary desiccation, and hence may elude direct observation for most sub-Neptunes in the near future. Helium/hydrogen enhancement is expected to be far more common, producing tenuous helium atmospheres over a large swath of sub-Neptune parameter space. Preliminary results suggest that the extent of helium/hydrogen enhancement may offer a way to distinguish between different mechanisms that sculpt planetary atmospheres, such as XUV-driven hydrodynamic escape and core-powered mass loss. Direct observations of such enhancement poses a challenge with current capabilities.

Gregory Cooke: Stellar UV uncertainties in 3D simulations of TRAPPIST-1 e lead to ambiguities in the interpretation of observations TRAPPIST-1e is a potentially habitable terrestrial exoplanet orbiting an ultra-cool M Dwarf star and a key target for observations with JWST. One-dimensional photochemical modelling of terrestrial planetary atmospheres has shown the importance of the incoming stellar UV flux in modulating the concentration of chemical species, such as O_3 and H_2O. Three-dimensional (3D) modelling has demonstrated anisotropy in chemical abundances due to transport in tidally locked exoplanet simulations. We use WACCM6, a 3D Earth System Model, to investigate how uncertainties in the incident UV flux, combined with transport, affect observational predictions for TRAPPIST-1e, assuming an initial Earth-like atmospheric composition. We use two semi-empirical stellar spectra for TRAPPIST-1 from the literature. The photochemically produced total O_3 columns differ by a factor of 24 between the simulations, with the depth of O_3 spectral features in transmission spectra leading to degenerate states (e.g. overlap with scenarios that assume alternative O_2 concentrations) when interpretating the observations. Without the direct detection of O_2, additional context for determining the oxygenation state of the atmosphere may be gained from future missions that can better characterise the UV spectra of faint stars, or sensitive multi-wavelength observations that span the visible and infrared regions.

Alfred Curry: Evolution of catastrophically evaporating planets Catastrophically evaporating exoplanets offer an intriguing avenue for investigating the composition of rocky exoplanets. These systems are observed through dusty tails made up of material evaporated from their molten surfaces. Here we present our model of the underlying solid/molten interiors of these planets. This is an essential part of linking the dust observations to general rocky planet compositions. The model calculates the thermal evolution, including heat flow through conduction and convection, partial melting, and mass loss. Using our model, we find that:

(1) The planets are likely to be almost entirely solid, for most of their lifetimes, other than a shallow lava pool on the dayside. The observed dust therefore only traces this small surface layer.
(2) The occurrence rate of planets which can undergo catastrophic evaporation, is higher than, but within an order of magnitude of, that observed for Super-Earths. This implies that exotic mechanisms to produce these systems may not be required.
(3) The temperature range of the observed systems are well explained by models where the outflows only produce dust for limited temperatures.

We also trace chemical species between the reservoirs of solid, melt and the tenuous escaping atmosphere to investigate the compositional evolution of the outflows.

Russell Deitrick: Climate response to an atmospheric resonance Earth's rotation period has gradually lengthened over geologic time to its present 24 hours due to the tidal recession of the moon. Today, the resulting semi-diurnal thermal tide, with its 12 hour period, is sufficiently far from the natural modes of slow atmospheric waves. Near the end of the Proterozioc Eon, however, the shorter rotation period may have lead to a resonance between the tide and these atmospheric waves. The thermal tide, which is a product of solar heating, can thus be resonantly enhanced by these wave motions. We present simulations of Earth's atmosphere across a range of rotation periods and plausible compositions, using the 3-D Earth system model CESM. We demonstrate that such a resonance can occur and that global surface temperatures increase as a consequence. The resonance enhances convective processes, resulting in a moister troposphere, which can lead to a warming comparable to a doubling of CO_2. We describe additional effects on clouds and the general atmospheric circulation. This resonance may thus have important implications for the past evolution of Earth's atmosphere.

Maria Di Paolo: Effect of ocean parameters on exoplanet climates The vast majority of research focusing on modelling exoplanetary climates uses atmospheric global circulation models of varying degrees of complexity, coupled to a slab ocean of fixed depth. While this type of study is certainly worthwhile and leads to important results, the lack of coupling to a dynamic ocean model precludes an accurate treatment of ocean circulation. Including the impact of ocean tides, ocean currents, their heat transport, and sea ice, can lead to significant qualitative differences in the results of exoclimate studies.

Feng Ding: Can we distinguish surface water distributions on arid rocky planets around M-dwarf stars by JWST? Many terrestrial planets in the habitable zones around M-dwarf stars may be water-poor as a result of their host stars' prolonged pre-main-sequence phase. Here I use an idealized general circulation model to explore the distribution of the remaining water inventory on synchronously rotating arid planets. Simulation results suggest that the remnant surface water reservoir can either be converged around the substellar region as an "oasis" (similar to Titan's polar methane lakes) or stably trapped on the nightside surface as ice caps (similar to Mars' polar CO_2 ice caps), owing to the cold-trapping competition between the substellar tropopause and cold surface regions. The possibility to identify those climate states on arid planets by the James Webb Space Telescope is discussed.

Jake Eager-Nash: Methanogen biosignatures on Archean like planets Life has played a key role in shaping the atmosphere since its origin on Earth and is likely to have played a similar role on inhabited exoplanets. However, the role of the host star is likely to play an important role in this interaction. M-dwarfs like Proxima Centauri or Trappist-1 have redder spectra with less radiation in the ultraviolet wavelengths that drive photochemistry. We look to explore this in more detail using coupled modelling of the biosphere and atmosphere. Methane producing organisms, or methanogens, are thought to have been present since the beginning of the Archean, which could have produced higher concentrations of methane on the early Earth. We look to understand potential methane fluxes from methanogen driven biospheres to understand on the atmospheric composition of Earth like planets orbiting different host stars and the role photochemistry plays in recycling methane back to hydrogen, which are consumed by methanogens. The amount of methane able to be stored in the atmosphere plays an important role in determining the strength of any potential biosphere. This work looks to understand the complex relationship between life and the environment on other worlds.

Ryan Felton: Temperate Venuses: CO_2 and terrestrial planets outside the conventional habitable zone Consensus suggests that the outer boundary of the habitable zone is set by the maximum greenhouse limit, where increasing atmospheric CO_2 no longer warms the planet but through enhanced Rayleigh scattering drives declining temperatures (Kopparapu et al. 2013). Beyond this threshold, other greenhouse gasses are needed to maintain clement surface conditions. For example, atmospheres with large molecular hydrogen abundances can extend the outer edge of the habitable zone well past the Kopparapu et al. values (Pierrehumbert et al. 2011). Unlike the carbonate-silicate cycle which provides the long term negative climate feedback to maintain temperate surface temperatures, there is no known process for hydrogen-dominated atmospheres. We present simulations of terrestrial atmospheres using a 1-D coupled photochemistry-climate model, Atmos, to study the effect that varying levels of CO_2 and H_2 have on surface temperature. Outside the conventional habitable zone, planets with substantial H_2 and CO_2 atmospheres could be buffered at modest surface temperatures by condensation of CO_2, which acts as a negative feedback on climate. These 'temperate Venuses' may be amenable to surface habitability, and we determine if these states of high CO_2 and H_2 can be maintained and whether liquid CO_2 pools persist over long time scales.

Jorge Fernandez: The atmosphere of ultra-hot Neptune LTT 9779 b survived thanks to an unusually X-ray faint star 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 Neptune desert. Its presence so close to its star is puzzling, as the intense X-ray flux it receives 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 the planet's atmosphere under photoevaporation. LTT 9779 b is one of the few planets that populate the Neptune desert, a region of parameter space at very short periods thought to be cleared out by stellar X-ray radiation, which drives substantial evaporation and can completely strip planets of their gaseous envelopes. LTT 9779 b, however, is the only known ultra-short period planet in the Neptune desert that maintains a significant atmosphere. In order to find feasible evaporation pasts that can explain its current state, I simulated the star's X-ray emission history and I find that the planet's atmosphere is only able to survive a faint stellar X-ray history that matches the measured upper limits for both its spin period and X-ray luminosity, which I estimated using XMM-Newton measurements.

Emeline Fromont: Atmospheric Escape From Three Rocky Planets in the L 98-59 System Atmospheric escape is an important factor in the evolution of exoplanet climates. We simulate the evolution of the L98-59 system and model atmospheric escape on its inner three small planets. We find that, regardless of their initial water content, all three planets accumulate significant quantities of oxygen due to efficient water photolysis and hydrogen loss. All three planets also lose high quantities of water, which would considerably affect their developing climates and atmospheres. Even in scenarios of low initial water content, JWST will likely observe retained oxygen on the L98-59 planets, allowing us to better study the climate development and atmospheric evolution of multi-planet systems of small rocky exoplanets.

Eric Gaidos: The Last Gas: Argon-Rich Atmospheres on Close-in Rocky Exoplanets Rocky exoplanets on close-in orbits are expected to rapidly lose their inventories of light, volatile elements due to atmospheric heating and escape. However, argon, the third most abundant element in Earth's atmosphere (1%) , may be more likely to be retained due to its high atomic weight and elevated ionization energy. In terrestrial planet atmospheres, argon can be continuously produced by radiogenic decay, and thus could accumulate over time. Although it will not produce a greenhouse effect and is unlikely to significantly affect heat transport, it could play a role in mobilization, levitation, and transport of dust and aerosols like that observed emanating from "evaporating" planets, which in turn could modulate the albedo and equilibrium temperature of the planet.

Tyler Gardner: Project PRIME: Measuring Phase Dependent Spectra of Non-Transiting Hot Jupiters with Interferometry We exploit the unique capabilities of long baseline interferometry to characterize the atmospheres of non-transiting hot Jupiters with Project PRIME. High resolution interferometers such as the CHARA Array and VLTI can resolve the planet-star distance to directly detect planets too close-in to study with single dish telescopes. We achieved a promising tentative detection with the MIRC-X instrument at CHARA of the hot Jupiter Ups And b at a contrast level of 2.2×10^{-4}, though we have yet to confirm the detection in K-band with the MYSTIC instrument. With injection tests we show that we are approaching the regime of measuring phase dependent spectra of Hot Jupiters in the near-infrared with this method. By comparing our observations with model spectra, we can better constrain global circulation models of such planets. This will be a promising technique in the era of Gaia, which will discover many close-in high contrast companions in need of characterization.

Hamish Innes: Convective inhibition and the runaway greenhouse limit on sub-Neptune water worlds Sub-Neptunes with hydrogen-dominated atmospheres and liquid water surfaces have been proposed as promising targets in the search for extraterrestrial life. In this work, we aim to quantify the inner edge of the sub-Neptune habitable zone using a 1D radiative-convective model. In particular, our model accounts for the inhibition of convection caused by a high mean molecular weight condensing species (water) increasing in abundance with depth in a hydrogen background atmosphere. Convective inhibition leads to super-adiabatic temperature gradients forming in the lower atmosphere, warming planets significantly and causing them to enter a runaway state at lower-than-expected instellations. For an M-star, this would move the inner edge of the habitable zone from 0.17 AU to 0.28 AU (0.54 AU) for a sub-Neptune with an atmospheric H2-He inventory of $10^4\,\mathrm{kg/m^2}$ ($10^5\,\mathrm{kg/m^2}$). Most current observational targets for habitable sub-Neptunes lie within this newly-calculated inner edge and are unlikely to be habitable assuming sustained convective inhibition. We present an analytic model of this system to help understand the lower instellation limit. We discuss the limitations of our 1D model and recommend the use of 3D convection-resolving models to explore the robustness of super-adiabatic layers.

Yui Kawashima: Subaru/IRD high-resolution spectroscopy of a T-type brown dwarf and investigation of its atmospheric properties with high-resolution spectrum model ExoJAX "Understanding the atmospheres of exoplanets and brown dwarfs holds the key to revealing their formation and evolutionary processes. Brown dwarf atmospheres share composition and temperature with those of extrasolar gas giant planets. In general, brown dwarfs are observable with a higher signal-to-noise ratio when compared to exoplanets. Thus, the observation of brown dwarf atmospheres helps us establish our understanding of various processes in the atmospheres of such temperature and composition, including chemistry, thermal structure, dynamics, and cloud formation. Also, their high-resolution spectra serve as excellent templates for the observational validation of the molecular line lists at such high temperatures. Molecular line lists play a critical role in the detection of chemical species in exoplanet atmospheres, which are often observed with a lower signal-to-noise ratio.

Recently, we observed a high-resolution spectrum of a T6.5-type brown dwarf Gl 229B with the InfraRed Doppler (IRD) spectrograph mounted on the Subaru Telescope. We have constrained its atmospheric properties, such as the molecular abundances and thermal structure, using an inverse-problem approach with our high-resolution spectrum model ExoJAX (Kawahara, Kawashima et al. 2022). In addition, we have revealed that in some wavelength regions, specific molecular line lists do not match the observed absorption features."

Engin Keles: The climate on HD189733b The gaseous exoplanet HD189733b is the first hot Jupiter in which Na has been detected at high-resolution. Previous investigations showed broad Na absorption lines with blue shifts, which hint at strong super-rotational and day-to-nightside winds. We revisit the Na-lines with the high-resolution spectrograph PEPSI at the Large-Binocular-Telescope, the largest telescope in the northern hemisphere, and show the most recent results regarding the wind structure on this planet.

Vigneshwaran Krishnamurthy: Atmospheres of low-mass star radius-gap planets And planets around low-mass stars ($< 0.8\,\mathrm{M}_\odot$) are in general rocky and are easier to detect and characterize using the transit technique. The atmospheric characterization of such planets provides a window in understanding the evolution of the planets. In general, small planets ($< 3\,\mathrm{R}_\oplus$) are expected to be accreted with 1-2% of H/He primordial atmosphere by the end of their protoplanetary disc dissipation (Owen & Wu 2017). This primordial atmosphere can be evaporated by the high-energy X-ray and EUV flux from their host star in the initial few million years. This photoevaporation process is dominant when the star is young and active (Owen & Wu 2013, 2017). Or the planet could dissipate the primordial atmosphere by its own internal heating of the cooling core. This core-powered mass-loss does not depend on the stellar environment, but just on the heat dissipating from the planet (Ginzburg et al. 2016, 2018; Gupta & Schlichting 2019, 2020). Finally, another class of models predict that the low-mass star planets essentially do not accrete enough gas during its formation (Lee et al. 2014; Lee & Chiang 2016; Lopez & Rice 2018). It is essential to distinguish between these models to have a robust prediction on the evolution of small planets. The distinction between these models can be achieved by observing planets in and around the transition region between rocky and non-rocky planets (a.k.a radius-gap; $1.5 - 2\,\mathrm{R}_\oplus$). Unfortunately, the origin of radius-gap is not clearly understood in low-mass star planets due to poor sample size in this region (Cloutier & Menou 2020). Here we present near infrared (NIR) high-resolution transit observations of GJ 9827b, GJ 9827d and TOI-1235b, small planets around cool stars. We target the He I triplet lines at 1083 nm as a marker for detecting any evaporating atmospheres (Oklopčić & Hirata 2018). The observations were carried out on several open use programs on the Subaru telescope infrared Doppler (IRD) instrument (R 70,000; Tamura et al. 2012; Kotani et al. 2018). Our study on probing the primary atmospheres can provide useful insights on the atmospheric evolution of low-mass star planets.

Brianna Lacy: A New Grid of Cold H2-He Dominated Atmosphere Models with Water Clouds and Nonequilibrium Chemistry We present a new suite of 1-d radiative-convective equilibrium models to aid in the JWST era of cold atmosphere characterization. Many temperate giant exoplanets have been detected by radial velocity but are not yet accessible via direct imaging. JWST can observe a handful of favorable cool exoplanets, but most remain out of reach for now. A larger number of Y dwarfs will be observable, and, indeed, such observations are already being carried out in JWST cycle 1 and GTO programs. Due to their similar temperatures but different formation histories, field Y dwarfs provide an informative analogue and comparison to the mature giant exoplanets we eventually hope to characterize. For the first time, we computed a large grid of models with both water clouds and nonequilibrium chemistry. Comparing models against literature Y dwarf observations, as well as preliminary JWST data, we find that nonequilibrium chemistry and water clouds can bring models and observations into better, though still not complete, agreement. Our findings make it clear that the two processes must be considered in tandem since the presence of clouds tends to warm atmospheric structures, leading to signatures of disequilibrium chemistry at lower effective temperatures than seen in clear atmospheres.

Maxence Lefevre: Impact of the deep convection in Brown Dwarf Atmospheres Numerous observational evidence has suggested the presence of active meteorology in the atmospheres of brown dwarfs. A near-infrared brightness variability has been observed. Clouds have a major role in shaping the thermal structure and spectral properties of these atmospheres. The mechanism of such variability is still unclear, and neither 1D nor global circulation models can fully study this topic due to resolution. In this study, a convective-resolving model is coupled to gray-band radiative transfer in order to study the coupling between the convective atmosphere and the variability of clouds. In addition, a chemistry scheme was coupled to study the impact of the strong vertical mixing on the C-H-N-O chemistry.

Binghan Liu: Higher Water Loss on Earth-like Exoplanets in Eccentric Orbits The climate of a terrestrial exoplanet is controlled by the type of host star, the orbital configuration and the characteristics of the atmosphere and the surface. Many rocky exoplanets have higher eccentricities than those in the Solar System, and about 18% of planets with masses $< 10\,\mathrm{M}_\oplus$ have $e > 0.1$. Underexplored are the implications of such high eccentricities on the atmosphere, climate, and potential habitability on such planets. We use WACCM6, a state-of-the9 art fully-coupled Earth-system model, to simulate the climates of two Earth-like planets; one in a circular orbit ($e = 0$), and one in an eccentric orbit ($e = 0.4$). We quantify the effects of eccentricity on the atmospheric water abundance and loss given the importance of liquid water for habitability. The asymmetric temperature response in the eccentric orbit results in a water vapour mixing ratio in the stratosphere ($> 20\,\mathrm{ppmv}$) that is approximately five times greater than that for circular orbit ($\sim 4\,\mathrm{ppmv}$). This leads to a ~ 3 times increase in the atmospheric hydrogen loss rate and a corresponding ~ 3 times decrease in the ocean loss timescale. Thus, highly-eccentric Earth-like exoplanets can still retain their oceans over the lifetime of the system. Using the Planetary Spectrum Generator, we simulate the idealised transmission spectra for both cases. We find that the water absorption features are stronger at all wavelengths for the $e = 0.4$ spectrum than for the circular case. Hence, highly-eccentric Earth-like exoplanets may be prime targets for future transmission spectroscopy observations to confirm, or otherwise, the presence of atmospheric water vapour.

Ana Lobo: From Tatooine to Endor: the Case for Water-limited Planets In the race to detect life beyond the Solar System, rocky M/K-dwarf planets are increasingly observable and offer exciting prospects. Planetary climate studies of these planets often assume an ocean-covered world. However, M-dwarf habitable zone planets are less likely to be born volatile rich, suffer enhanced heating and high-energy radiation during early stellar evolution, and persistent flares. Water-limited land-planets may be especially common in the M-dwarf habitable zones, but are chronically understudied.

Land-planets can have uniquely diverse climates. Our recently published work shows that, unlike aquaplanets, they can be in a "terminator habitability" climate regime. They can sustain larger temperature gradients, such that, with scorching dayside and freezing nightside temperatures, the habitable zone is confined to a ring at the terminator. Meanwhile, comparable aquaplanets lose water to nightside cold-trapping or water vapor escape, limiting water availability over time.

At Exoclimes I will show how these results, combined with observational advantages for arid planets, indicate land-planets will be abundant and convenient candidates for early detections of habitability. I will also compare results for M- and K-dwarf planets, quantifying the "K-dwarf advantage" for land-planets, especially pertaining to precipitation patterns and long-term water availability, making the case for habitability on water-limited worlds.

Evelyn Macdonald: Water Vapour Transit Ambiguities on Habitable M-Earths, This work uses simulations to connect surface conditions to observables for tidally locked, habitable zone rocky planets (M-Earths). JWST will produce transit spectra of several M-Earths in the coming years, but will not be able to observe their surfaces directly. Nonetheless, the amount and location of land on a planet can have significant climate effects, as can the mass of its atmosphere. In this work, I use the 3D climate model ExoPlaSim to systematically vary land cover and atmosphere mass on an M-Earth. I then use the radiative transfer model petitRADTRANS to generate synthetic water vapour transit spectra from my climate simulations. I will discuss how climates respond to variations in land cover and atmosphere mass, and show that it will be difficult to differentiate between climate regimes using transit spectroscopy when these parameters are unknown. Since both land cover and atmosphere mass will be difficult to measure for a given planet, these sources of uncertainty will need to be accounted for when interpreting observations.

Adrien Masson: Constraining exoplanet atmospheric escape in the near-infrared with SPIRou Studying the processes involved in the atmospheric escape of short-period gaseous exoplanets is a key stake in our understanding of the formation, evolution, and population of exoplanets in general. A famous example is the so-called "sub-Neptune desert", for which atmospheric escape is believed to play a crucial role. Since recent years, ground-based high-resolution spectroscopy in the near-infrared allows us to probe the atmospheric escape of transiting exoplanets through the observation of the metastable He triplet lines at 1083.3nm, providing us with a new window for atmospheric escape in addition to the observation of H lines in UV and visible.

With a high spectral resolution power of 70,000 and a large continuous spectral range between 0.9 and 2.5 microns, the near-infrared spectro-polarimeter SPIRou on the CFHT is a powerful instrument for exoplanet atmosphere characterization since its first light in 2018. I will present new constraints regarding atmospheric escape in a dozen of transiting short-period exoplanets, ranging from hot jupiters to sub-Neptune, observed with the SPIRou instrument. I will first introduce the data reduction methodology, and then present our detection and upper limits obtained using two different models for comparison purposes."

Tobias G. Meier: Hemispheric tectonics on tidally locked super-Earths Many super-Earths are very close-in to their host star and are therefore likely to be tidally locked. Tidally locked super-Earths experience intense solar heating on their permanent dayside, whereas the nightside surface can reach extremely cold temperatures. For the case of super-Earth LHS 3844b, a bare-rock super-Earth with a radius of 1.3 Earth radii, we have shown that this strong surface temperature contrast can lead to a so-called hemispheric tectonic regime, which is characterised by a strong downwelling on one hemisphere and upwellings that rise on the other side. Here, we focus on super-Earth GJ 486b, which has also a radius around 1.3 Earth radii, but for which it is unknown whether it was able to retain an atmosphere. We use GCMs to constrain the surface temperature assuming different efficiencies of atmospheric heat circulation. Our results show that hemispheric tectonics could also operate on super-Earth GJ 486b, even for more moderate surface temperature contrasts. Upwellings that rise preferentially on one hemisphere could lead to generation of melt and subsequent outgassing of volatiles on that side. Imprints of such outgassing on the atmospheric composition could possibly be probed by current and future observations such as JWST, ARIEL, or the ELT.

Erik Meier: A CHEOPS exploration of the photometric modulation phased with the super-Earth 55 Cnc e Among the handful of super-Earth exoplanets discovered, 55 Cnc e is arguably the most studied one and yet its 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, among others. The CHaracterising ExOPlanet Satellite (CHEOPS) observed 55 Cnc a total of 29 times 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 on 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.

Fabienne Nail: Revealing the Anisotropy of Evaporating Exoplanet Atmospheres The hydrodynamic escape atmospheres can have major implications for the evolution of close-in planets and has been proposed as an underlying cause of the observed lack of short-period Neptunes. We explore how the interaction between the planetary and stellar wind affects the properties of the observed He-1083 nm line. We focus on anisotropic atmospheric escape using 3D hydrodynamic simulations. We investigate how the stellar wind shapes the planetary outflows with varying degrees of day-night anisotropy and generate synthetic transmission spectra and light curves in the He 1083 nm line. For day-to-night anisotropic structures, we find an overall blue shift of the helium line center of a few km/s compared to the isotropic case. Furthermore, we find a correlation between the blueshift and the degree of assumed anisotropy. The shape of the helium line is also affected, as it becomes narrower at a higher degree of anisotropy. These findings may enable identifying avenues for the characterization of asymmetric outflow geometries through helium observations.

Evert Nasedkin: So you've found a planet, now what do you do with it? In direct imaging, the characterisation of exoplanets has always been a somewhat secondary goal to actually finding the targets in the first place. It is only with the development of current instrumentation that we can characterise these young, giant objects in detail. Even still, this is no simple task. In this talk, I will present the challenges of inferring atmospheric properties through Bayesian retrievals. Using a combination of data from VLTI/GRAVITY and other high contrast instruments, we can present the results of applying these methods to the benchmark system of HR 8799: systematically exploring the atmospheres of all four planets in the system.

Harrison Nicholls: Stellar flares and gas giant atmospheres, with coupled temperature and non-equilibrium chemistry The effect of enhanced UV irradiation associated with stellar flares on the atmospheric composition and temperature of gas giant exoplanets was investigated. This was done using a 1D radiative-convective-chemical model with self-consistent feedback between the temperature and the non-equilibrium chemistry. It was found that flare-driven changes to chemical composition and temperature give rise to prolonged trends in evolution across a broad range of pressure levels and species. Allowing feedback between chemistry and temperature plays an important role in establishing the quiescent structure of these atmospheres, and determines their evolution due to flares. It was found that cooler planets are more susceptible to flares than warmer ones, seeing larger changes in composition and temperature, and that temperature-chemistry feedback modifies their evolution. Long-term exposure to flares changes the transmission spectra of gas giant atmospheres; these changes differed when the temperature structure was allowed to evolve self-consistently with the chemistry. Changes in spectral features due to the effects of flares on these atmospheres can be associated with changes in composition. The effects of flares on the atmospheres of sufficiently cool planets will impact observations made with *JWST*. It is necessary to use self-consistent models of temperature and chemistry in order to accurately capture the effects of flares on features in the transmission spectra of cooler gas giants, but this depends heavily on the radiation environment of the planet.

Stephanie Olson: Superhabitability of High-Obliquity and High-Eccentricity Exoplanets Obliquity and eccentricity influence planetary climate by shaping the spatial and temporal patterns of stellar energy incident at a planet's surface, affecting both the annual mean climate and magnitude of seasonal variability. Previous work has demonstrated the importance of both obliquity and eccentricity for habitability, but most studies have not explicitly considered the response of life to these parameters. We used a 3D marine biogeochemical model coupled to an atmospheric general circulation model (cGENIE-PlaSim) to investigate how Earth's biosphere would respond to obliquities up to 90 degrees and eccentricities up to 0.4. We found that biological activity increases with obliquity and eccentricity across the entire parameter space that we considered. This presentation will explore the mechanisms leading to enhanced productivity on worlds experiencing extreme seasonality and will ultimately argue that high-obliquity and/or high-eccentricity exoplanets may be among our most promising targets for life detection.

Kimberly Paragas: A Framework for Simultaneously Retrieving Atmosphere and Surface Properties of Hot, Rocky Exoplanets JWST's Mid InfraRed Instrument (MIRI) provides a unique opportunity to search for signatures of exoplanet surfaces with low resolution spectroscopy. Close-in, rocky planets orbiting M dwarfs are ideal targets for these studies. Though these planets are likely to have completely lost their primordial H/He atmospheres, they may outgas secondary, high mean molecular weight atmospheres. Consequently, it is important to consider how the presence of such an atmosphere with unknown mass and composition would impact our ability to robustly characterize the surfaces of rocky exoplanets.

We modified the open-source Python package PLATON (Zhang et al. 2020) to perform simultaneous atmosphere and surface retrievals on secondary eclipse measurements of rocky super-Earth planets. These new features, including the ability to constrain different surface types through spectral features in emission and an improved prior scheme for retrieving an arbitrary mixture of atmospheric gases, will be made publicly available in a future release of PLATON. We demonstrate the capabilities of this framework on simulated secondary eclipse observations of the archetype super-Earth LHS 3844 b for scenarios in which the planet has (1) no atmosphere, (2) a thin atmosphere ($P_{\rm surf} < 1\,{\rm bar}$), and (3) a thick atmosphere ($P_{\rm surf} = 1\,{\rm bar}$).

Caprice Phillips: A Holistic Retrieval Approach for an Intermediate Mass Brown Dwarf: IRXS J2351+3127B. Do the lowest mass brown dwarfs form like binary stars through gravitational collapse of an interstellar molecular cloud or via processes similar to theorized planetary formation (e.g. core accretion or disk instability)? We are performing atmospheric characterization through joint high resolution and low resolution retrieval analysis of the substellar companion IRXS J2351+3127B. This object serves as a bridge between high mass benchmark brown dwarfs and low surface gravity directly imaged exoplanets and is one of the lowest mass members (model dependent mass of $32 \pm 6\,{\rm M_{jup}}$) in the 50 -150 Myr AB Dor Moving Group. IRXS J2351+3127B is a brown dwarf companion (spectral type = L0 to an early M-dwarf (M2) host) and the system has a separation of 120 AU. We will present initial findings of the first steps in our three part spectral retrieval analysis. Our initial analysis uses the Brewster retrieval framework (Burningham et al. 2017, 2021) on the low-resolution Spex-prism data. This target will be used as a test case to build upon retrieval codes and continue validation and testing of joint high-resolution (from Keck Planet Imager and Characterizer (KPIC) [R = 35,000 in the K-band]) and low-resolution near-infrared spectral data.

Mark Phillips: The carbon-to-oxygen ratio in cool brown dwarfs and giant exoplanets The carbon-to-oxygen (C/O) ratio in brown dwarfs and gas-giant exoplanets provides a link between present atmospheric composition and formation pathway, allowing studies into the complex and uncertain origins of these objects. Measurements of the C/O ratio in brown dwarfs are severely lacking, in large part due to past deficiencies in atmosphere models. To address this, we have been expanding our recently published ATMO 2020 atmosphere model grid to include non-solar carbon-to-oxygen ratios, benefitting from a range of improvements to the molecular opacities and chemistry. Crucially, these new models reveal that we cannot reliably disentangle the C/O ratio of cool brown dwarfs from other atmospheric processes with the spectral resolution, signal-to-noise and/or incomplete wavelength coverage of spectra currently available in the literature. We have therefore obtained high-quality Gemini/GNIRS spectroscopy that, combined with our state-of-the-art atmosphere models, enable us to constrain the atmospheric parameters and C/O ratios for a sample of cool brown dwarfs and free-floating planets. We will present our recent advances in comparing the ATMO 2020 models to this new dataset.

Federica Rescigno: MAGPy: a pipeline for Gaussian Processes for planetary detection Breaking the stellar activity radial velocity barrier is vital for the detection and char- acterisation of exoplanets, in particular small Earth-like planets. A planetary RV signal can be easily drowned or mimicked by RV variations generated by activity on the surface of the host star. Gaussian Process Regression, paired with Markov Chain Monte Carlo parameter space exploration, is a powerful tool for modelling these stellar-induced signals to be subtracted from the raw data, and for searching the Keplerian model that best fits the reduced data at the same time. I present an in-process GP Regression and MCMC optimisation pipeline for exoplanetary RV detangling, MAGPy. I will also present a detection of a two planet system around a high-proper motion K-dwarf: an inner short period Neptune and an outer highly eccentric long-period temperate sub-Saturn, both viable for follow-up atmospheric detection.

Matthäus Schulik: Multi-species hydrodynamic escape along the Sub-Neptune/Super-Earth divide Photoevaporating planetary winds have been proposed as important mechanism contributing to the evolution of the volatile inventory in close-in planets, explaining the observed radius valley for low-mass exoplanets at around $r \sim 1.7\,R_{\rm Earth}$. Molecules originating a planets' lower atmosphere can be entrained in the escaping hydrogen wind and dissociated by energetic photons on their way to higher altitudes into their atomic constituents. These minor species can contribute strongly to the total cooling capability in the outflow, and hence impact the mass loss rates significantly. In this work, we use a 1-D multi-species radiation hydrodynamics code in conjunction with photochemistry, in order to investigate the mass loss-rates and thermal structure of outflows from those exoplanets. We will discuss impacts of the birth properties of exoplanets, parameterized by their atmospheric C/O and C/H values, on the early mass-loss behaviour. Following that, the depletion of atmospheric hydrogen content along an evolutionary sequence and its final abundance is discussed. We close with a brief discussion of radius evolution scenarios to be tested with upcoming JWST observations.

Hinna Shivkumar: The V1298 Tau system - An update on the young multi-planetary system as observed by CHEOPS, HST and Spitzer Young planets form a unique bridge between planet-forming protoplanetary disks and mature planets. In order to infer the internal and atmospheric structure of these young inflated planets, it becomes important to have high-precision measurements of their mass and radius. The V1298 Tau system, only a mere 23 Myrs old, is a keystone multi-planetary system hosting four transiting planets. Since the planets orbit a highly variable star, constraining the mass of the planets using radial velocities becomes a challenge. In such a scenario, using transit-timing variations (TTVs) provides another avenue to constrain the mass of the planets.

In this talk, I will present high-precision transit observations of the first three planets in the V1298 Tau system using the CHEOPS telescope. I will provide an insight into the data analysis methodology used to encounter the unique systematics of CHEOPS. I will also briefly discuss the decorrelation methods used to tackle stellar variability evident in the observations. Finally, I will present the improvement in the transit parameters of the three young planets, place these observations in the context of HST and Spitzer observations of this system, and discuss how these observations will help in constraining the mass of the planets using TTV models.

James Sikora: Partial Phase Curve of the Highly Eccentric Hot Jupiter HD 80606 b Observed With NIRSpec High-eccentricity gas giant planets serve as unique laboratories for studying the thermal and chemical properties of H/He-dominated atmospheres. In certain cases, the orbit-induced changes in incident flux can significantly alter the atmosphere's temperature profile and allow the thermal timescales, chemical timescales, and the composition of aerosols to be constrained. One particularly remarkable case is that of HD 80606 b (M=4.2 Mjup, R=1.0 Rjup, P=111 d, e=0.93), which experiences an increase in incident flux of nearly three orders of magnitude between the apoapsis at 0.9 au and the periapsis at 0.03 au. Due to it's orbital configuration and the high brightness of it's host star (spectral type G8V, J=7.7 mag), changes in the atmosphere's thermal and chemical structure predicted to occur during the periapse passage can potentially be detected using JWST. Here we will summarize these predictions and how they compare with partial phase curve/eclipse observations of HD 80606 b obtained with NIRSpec during Cycle 1.

Jared Splinter: Performance of Longitudinally Resolved Spectral Retrieval for Future Exoplanet Observations Previous implementations of 1D exoplanet spectral retrieval use the disk integrated retrieval method, which assumes the planet's atmosphere is spherically symmetric. phase curves on a 2D framework has shown to provide more accurate and self-consistent results. Unfortunately, this comes with an increased trade-off of increased model complexity and increased parameter space that can make results more difficult to interpret and validate. As planets are intrinsically 3D in nature, we would prefer a retrieval approach that is not too simple to miss important aspects of the atmosphere, while also not being not too complicated to make fitting and explanation more difficult. Exoplanet phase observations can be fitted with a Fourier series that can be analytically converted to longitudinal maps. By treating each wavelength independently, this will produce a longitudinal map of an exoplanet at each wavelength. This in turn, creates longitudinally resolved spectra capable of conducting retrieval on spectra from longitudinal slices of the planet which can be fit to pre-existing 1D spectral retrieval codes. This work aims to compare the performance of longitudinally resolved and disk integrated spectral retrieval methods on synthetic spectra of HD 189733b and establish a recommendation for future exoplanet observations with JWST and ARIEL.

Christiaan Van Buchem: Self-sustaining water atmospheres on magma planets and their observability With hundreds of hot-rocky exoplanets discovered and a dozen of good targets for JWST characterisation, understanding the links between the interior and atmospheres of these worlds and what we can learn from the observations is more relevant than ever.

Hot-rocky exoplanets with a significant volatile atmosphere are thought to be able to support long-term global magma oceans. Recent interior modelling work has shown that if the surface temperature of these planets is above 2000K, the mantle is likely to be molten down to the core-mantle boundary. This is in stark contrast to the fact that the mantle is almost entirely solid for surface temperatures below 1900K. This has considerable implications for the storage of water in the mantle of these planets and the amounts that are expected to be found in their atmospheres. Within a margin of about 100K, the water storage capacity of the mantle changes by up to three orders of magnitude.

In this presentation, we will show how planets with long-term magma oceans are expected to evolve, and which are the consequences of such evolution on their atmospheres. We will also discuss the implications of this in the exoplanet population and in the observability of such worlds.

Iris van Zelst: Towards coupled interior-atmosphere models of Earth and Venus The evolution of the composition of planetary atmospheres is largely determined by the partial melting and volcanic outgassing of the planetary interior. In turn, the composition of the atmosphere dictates the surface temperature of the planet (due to processes like the greenhouse effect), which is an important boundary condition for crustal and mantle processes in the interior of a planet. Venus in particular has a thick atmosphere at present with an abundance of the greenhouse gas CO_2 and a small amount of water vapour. The evolution of the surface temperature and therefore its convective regime is thought to be significantly affected by volcanic outgassing throughout the thermal evolution of Venus. To study this coupling between the interior and the atmosphere of a planet holistically, coupled models are needed that consider both the large-scale geodynamics of a planet and the atmosphere resulting from outgassing. Here, we present progress on two projects that attempt to do this: 1. interior-atmosphere coupled models that consider CO_2 and H_2O on Venus; and 2. a radiative transfer model aimed at increasing our understanding of the hypothesised early Earth's steam atmosphere after its magma ocean phase.

Vidya Venkatesan: The Radiative effects of Surface $\mathbf{CO_2}$ ice on the Climatic Evolution of Extrasolar planets Eccentric planets may spend a significant portion of their orbits at large distances from their host stars, where low temperatures may lead to the condensation of atmospheric carbon dioxide (CO_2), which can be found on the poles of Mars. Due to its wavelength-dependent albedo, the radiative effects of surface CO_2 ice will vary depending on the host star type. We quantify the radiative impact of surface CO_2 ice on the climate stability of planets orbiting different stars across multiple eccentricities by including a CO_2 ice-albedo parameterization into a 1-D energy balance model. When this parameterization is included, M-dwarf planets require 70% more flux to exit a globally-glaciated state than with a traditional pure water ice-albedo parameterization. Above e=0.5, the intense heat at periastron aids planets in exiting a snowball state with a smaller percentage increase in instellation than planets on circular orbits, such that despite CO_2 ice accumulation, planets orbiting at large distances are less susceptible to snowball states than planets on circular orbits. This work indicates the importance of incorporating CO_2 ice-albedo parameterization to accurately assess the habitability of eccentric planets that may get cold enough for CO_2 to condense onto their surface.

Xinting Yu: Identify Surfaces on Sub-Neptunes in the JWST Era Sub-Neptunes remain the most abundant type of detected exoplanets. However, it remains challenging for upcoming observations to directly identify the surface conditions (temperature $T_{\rm surf}$ and pressure $P_{\rm surf}$) on these intermediate-sized exoplanets. Recently, it has become clear that the atmospheric characterization of these intermediate-sized exoplanets, measurable by JWST, could offer insights into their surface conditions (Yu et al. 2021, Tsai et al. 2021, Hu et al. 2021). This is because the surface conditions of an exoplanet have a direct impact on the abundance of many atmospheric trace species, as a result of the feedback between the atmosphere and the surface through photochemistry, transport, and thermochemical equilibrium. In this work, we explored the applicability of the surface identification framework towards cooler exoplanets ($T_{\rm eq} < 200\,{\rm K}$), where condensation is important, and hotter exoplanets ($T_{\rm eq} > 300\,{\rm K}$), where thermochemical equilibrium is promoted at the lower boundary. Given these results, we identified a range of JWST targets that allows us to conduct the surface identification framework.

Daniel Williams: Clouds and Seasonality on Terrestrial Planets with Varying Rotation Rates. Whilst we are very familiar with the distribution of clouds that we observe on Earth, we understand less about where clouds may form on other terrestrial planets. Clouds have been observed on Venus, Mars and Titan, and a growing number of exoplanets, however the connection between planetary rotation rate and cloud distribution has not been explored until now. Using an idealised climate model incorporating seasonal forcing, we investigate the impact of rotation rate on the abundance of clouds on an Earth-like aquaplanet, and the resulting impacts upon albedo and seasonality. We show that the cloud distribution varies significantly with season, depending strongly on the rotation rate, and is well explained by the large-scale circulation and atmospheric state. Planetary albedo displays non-monotonic behaviour with rotation rate, peaking at around one quarter of Earth's rotation rate. Clouds reduce the surface temperature and total precipitation relative to simulations without clouds at all rotation rates. Clouds also affect the amplitude and timing of seasonality. They have a relatively smaller impact on seasonality at slow rotation rates, but they decrease the width of the Hadley cell at intermediate rotation rates. The timing of seasonal transitions varies with rotation rate; the addition of clouds further modifies this phase lag, most notably at Earth-like rotation rates.

Joe Zalesky: The Hobby-Eberly Telescope Survey of Helium Exosphere Outflows Atmospheric escape is the central process driving the evolution and observable state of many short-period exoplanets. However, the exact physical mechanisms which drive this escape, and their relative impacts on the total mass loss, are still unknown. In order to better understand this process, a large sample of mass loss rates from actively escaping atmospheres, observed across a range of both stellar and planetary properties, is needed to distinguish between several mechanisms within the literature (e.g. giant impacts, photoevaporation, stellar wind). One of the best ways to measure the mass loss from the ground is through high spectral resolution observations of the He 10830 Å triplet lines in the planet's exosphere. In this work we present results from observations of the He 10830 Å triplet using the Habitable-zone Planet Finder (HPF) Spectrograph aboard the Hobby-Eberely Telescope (HET) of 19 different planets across a range of spectral types and planetary properties. Our survey's high time baseline allows us to establish with high confidence multiple detections of escaping helium across a broad range of stellar and planetary parameter space. We present our target selection strategy, data and modeling analysis, and key results from our confirmed detections.

Ruizhi Zhan: The Inner Edge of Habitable Zone Around White Dwarfs White dwarf stars offer a unique opportunity to search nearby stellar systems for signs of life. Due to white dwarfs' small size, planets orbiting these stars are much easier to characterize via transmission spectra than planets orbiting main sequence stars. The potential habitability of white dwarf planets, however, is still poorly understood. Here we use the ExoCAM global climate model (GCM) to investigate the inner edge of the habitable zone (HZ) around white dwarfs. Since white dwarfs are low-luminosity and compact, habitable planets orbiting them are most probably tidally locked and rapidly rotating with orbital periods ranging from hours to days. Consequently, we find that the runaway greenhouse limit for white dwarfs lies in-between previous results for fast rotating non-tidally locked planets and slowly rotating tidally locked planets. The upper atmospheres of white dwarf planets are also much drier than for main sequence stars, which means most white dwarf planets never experience a moist greenhouse state. We explain these features as resulting from unusual atmospheric circulation regimes. When tidally locked planets rotate rapidly (orbital period $\lesssim 1$ day), the hottest point on the planetary surface shifts from the equator to the subtropics which leads to the formation of anti-Hadley Cells on the planet's dayside and a cooling effect. The habitable zone inner edge around white dwarfs is therefore strongly affected by planetary rotation, the dynamics of which cannot be resolved in 1D models.