Layers of Understanding:
Model Intercomparisons of Exoplanet Interiors

Abstract booklet

(in alphabetical order)

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Artyom Aguichine, *Natalie Batalha, Jonathan Fortney, Yao Tang, Madeline Lessard*
Volatile content of sub-Neptunes based on interior models (online)
More than 6000 exoplanets have been discovered to this day, and sub-Neptunes represent the largest population by number. The size distribution of sub-Neptunes also shows that they are separated into two categories: a smaller population (~1.5 Re) suggesting a rocky structure, super-Earths, and a larger population (~2.4 Re) suggesting the presence of a thick envelope of volatile material, mini-Neptunes. However, the nature of the volatiles making up the envelopes of mini-Neptunes is unknown. One end-member is a dry rocky core that accreted a small amount of H2-He from the protoplanetary disk, labeled gas dwarfs. The opposite end-member is a planet that formed from ice-rich pebbles or planetesimals but accreted no gas. These hypothetical planets have up to 50% of their mass in the form of heavy volatiles, generally assumed water, hence labeled water worlds. In reality, any intermediate composition is also possible, and there are great expectations that atmospheric spectroscopy can break this degeneracy. In the meantime, the true nature of sub-Neptunes remains unknown, so their modeling must be performed in a conservative way. In this work, we develop a new framework to infer the bulk volatile content of sub-Neptunes based on interior structure models on a demographic level. We describe the fitting procedure and two steps that require particular attention to ensure meaningful results. We remain agnostic on the true nature of sub-Neptunes, and use state-of-the-art interior structure models of gas dwarfs and steam worlds. This gives us the distribution of volatile content in sub-Neptunes for both scenarios. These distributions can be confronted to planet synthesis models to provide additional clues to the true nature of sub-Neptunes.

Babatunde Akinsanmi, *Monika Lendl*
Measuring exoplanet Love numbers with JWST and PLATO (online)
The discovery and characterization of exoplanets have revolutionized our understanding of planetary systems, with Ultra-Hot Jupiters (UHJs) representing one of the most extreme and intriguing classes of exoplanets. These gas giants, with equilibrium temperatures exceeding 2000 K, orbit their host stars at extremely close distances, leading to intense stellar irradiation and significant tidal interactions. The extreme conditions of UHJs make them ideal laboratories for studying the effects of stellar radiation, tidal forces, and atmospheric dynamics on planetary evolution. However, the interior structure of these planets remains poorly understood, primarily due to the lack of precise observational constraints since using only mass and radius measurements leads to degenerate results. The planet's response to tidal forces, its tidal deformation, provides an additional observable to better constrain the interior structure. More precisely, phase curves and transits can be used to measure the second fluid Love number for radial deformation, h2, which depends on the radial distribution of mass within the planet. Current observations from missions like CHEOPS and TESS have provided preliminary constraints on the Love numbers of a few UHJs, such as WASP-12b and WASP-103b, but the precision of these measurements is limited by the photometric noise. PLATO's high-precision, long- duration photometry will enable more accurate measurements of the Love numbers from phase curves, allowing us to distinguish between different interior models. In this talk, I will present the capability of PLATO and JWST in improving the interior structure of UHJs.

John Allen, *Thaddeus Komacek, Joost Wardenier, Louis-Phillipe Coulombe*
Interior evolution, GCM models, and JWST observations of WASP-76b (in person)
We present a suite of General Circulation Models (GCMs) and interior evolution models of the ultra-hot Jupiter WASP-76b using the SPARC radiative transfer model in the ADAM framework (formerly the SPARC/MITgcm) and compare the results to recently obtained JWST NIRSpec/G395H phase-curve and emission data. We vary a spatially independent atmospheric drag term, representing effects such as Ohmic dissipation, turbulent mixing, shocks, and hydrodynamic instabilities, suppressing the atmospheric flow within the atmosphere. We also run models with and without clouds (enstatite and corundum). We also use a grid of MESA models with a custom interior heating routine to predict heating strengths and depths required to match the present-day radius. We find that relatively weak

heating within the deep envelope, beneath the radiative-convective boundary, is sufficient to inflate the planet enough to match the present-day radius. We then use the output 200 bar temperatures to fix the bottom boundary temperature of the GCM in some runs. We also compare the final radii and interior profiles predicted by different interior evolution models: base MESA (no core), MESA with a simple heavy-element core, MESA with a self-consistent compressible core, and a custom PROTEUS model suitable for gas-giant evolution. We post-process the GCM outputs using the gCMCRT radiative transfer code. We find that strong drag and cloudy nightsides provide the best fit to the James Webb phase-curve data. The requirement for strong drag to match phase-curve data aligns with results for other ultra-hot Jupiters (WASP-18b, WASP-103b, WASP-121b), from both Spitzer and JWST phase-curves. We find that producing fits to the emission spectra require careful consideration of the atmospheric composition. We find that interior heating has little effect on the observational properties of the planet, with the main observational effects being from the varying atmospheric drag.

Rahul Arora, *Sukrit Ranjan, Ananya Mallik, Pranabendu Moitra*

Thin H2-Dominated Atmospheres as a Diagnostic of Exovolcanism (online)

Magmatic outgassing plays a critical role in replenishing atmospheres and shaping planetary climate. It is intimately linked to a planet's interior and influences its geological evolution, atmospheric composition, and potential habitability. With our current observation capabilities, the detection of magmatic outgassing signatures requires low mean molecular weight (μ) atmospheres. However, close-in rocky exoplanets are expected to lose their primordial H2 envelopes due to intense atmospheric escape, leaving behind thin, high-μ secondary atmospheres or no atmospheres. We investigate whether magmatic outgassing can sustain low-μ atmospheres on close-in rocky exoplanets, making the detection of a H2-dominated atmosphere a potential indicator of active magmatic outgassing. We propose tidal heating as a source of higher melt production and estimate the resulting outgassing fluxes for all planets in the TRAPPIST-1, L~98-59, and L~791-18 systems to identify candidates where outgassing may exceed escape. We model outgassing fluxes across a broad parameter space, varying mantle redox state and initial volatile inventories of C, H, and S. We find that reducing mantles and higher H2O inventories favor H2 outgassing. Under mantle conditions more reducing than ~FMQ-4.5 and water inventories exceeding ~1 wt%, planets such as L~98-59~d could theoretically sustain geologically long-lived secondary H2-dominated atmospheres. We propose "outgassing zone" as the region around a star where tidally-driven magmatic outgassing can exceed hydrodynamic escape for given planetary conditions. Additionally, we show that while primordial H2 is a false positive for magmatic outgassing, precise mass–radius constraints can distinguish this false positive. These secondary atmospheres offer promising opportunities to detect magmatic outgassing signatures with JWST. We assess their detection feasibility across a range of planetary conditions, highlighting key targets for future observations.

Mara Attia, *Tim Lichtenberg*

PALEOS: A centralized Python toolkit for planetary material equations of state (in person)

Modeling the interior structure of rocky exoplanets requires accurate thermodynamic properties of constituent materials across extreme pressure–temperature conditions. While several equations of state (EoS) exist in the literature for relevant planetary materials, they are scattered across disciplines, sometimes contain errors, and lack standardized implementations, forcing each modeling group to independently reconstruct these relations. We present PALEOS (Planetary Assemblage Layers: Equations Of State), an open-source Python package providing validated, analytically-derived thermodynamic properties for planetary interior modeling. For any pressure–temperature point, PALEOS returns density, specific internal energy, specific entropy, isobaric and isochoric heat capacities, thermal expansion coefficient, and adiabatic gradient, quantities essential for structure integration and thermal evolution calculations. The initial release covers iron across its full phase diagram relevant to planetary cores: ε-hcp, γ-fcc, α-bcc, δ-bcc, and liquid, with phase boundaries ensuring numerical stability at transitions. We extend coverage to silicate mantles with $MgSiO_3$

enstatite, bridgmanite, postperovskite, and liquid phases, and to water envelopes with updated AQUA tables correcting known entropy inconsistencies. Alongside the Python API, we provide ready-to-use pressure–temperature tables spanning conditions from terrestrial planets to super-Earth cores (up to 10 TPa), updated mass–radius relationships, and ternary composition lines for iron–silicate–water mixtures. By centralizing validated implementations with analytical derivations, comprehensive benchmarking, and consistent interfaces, PALEOS aims to improve reproducibility and most importantly accelerate characterization efforts for both interior modelers and observers.

Jacob Ayre, *Anjali Piette, Peter Gao*
The impact of hazes on Sub-Neptune interior conditions and evolution (in person)
Photochemical hazes have been detected and are likely common in sub-Neptune atmospheres, yet their impact on interior conditions and evolution remains largely unexplored. The optical properties of hazes affect an atmosphere's temperature profile and a planet's ability to radiate, and hence cool. This can happen by, for example, reflecting starlight or by potentially insulating younger, warmer planets. To model this, we use a 1D radiative-convective atmosphere model (GENESIS) coupled with an aerosol microphysics code, the Community Aerosol and Radiation Model for Atmospheres (CARMA). We investigate how different haze types and production rates impact the temperature profiles of sub-Neptunes at different evolutionary stages. We discuss the implications for sub-Neptune cooling rates, thermal evolution and interior conditions.

Philipp Baumeister, *Zahra Ali, Alexander Thamm, Lena Noack*
Machine-learning retrievals of rocky exoplanet interiors (in person)
Planets form from the same dust and gas cloud as their host star. Consequently, the refractory composition of rocky planets is expected, in principle, to resemble that of the host star, albeit modified by formation and migration processes. Measurements of the stellar Fe/H ratio can therefore help, in combination with planet mass and radius, to significantly constrain planetary interior structures. However, conventional interior retrieval methods are typically computationally expensive and time consuming, which limits their applicability to large-scale population studies. We here employ our machine-learning-based framework ExoMDN (Baumeister & Tosi 2023) to construct an interior retrieval model that accounts for planet mass, radius, orbital distance, and stellar Fe/H ratio. ExoMDN requires a large training dataset of synthetic planets, which we generate by combining a condensation model to estimate the chemical compositions of stars and planets (Carone et al., 2025) with a rocky planet interior structure model (Noack & Lasbleis, 2020). In total, we produce more than one million synthetic planets with randomly sampled stellar and planetary masses, orbital distances, and stellar metallicities. The trained model rapidly infers probability distributions of possible interior structures within fractions of a second, enabling the large-scale characterization of rocky exoplanet interiors.

Armin Bergermann *(Invited)*
TBD

Anand Bhongade, *Anjali Piette, Caroline Dorn, Aaron Werlen, Simon Grimm and Edward Young*
Endogenous or accreted? Interpreting H2O in sub-Neptune atmospheres (in person)
The interior compositions of sub-Neptunes remain an important question in the field. A key challenge is that atmospheric observations probe the upper atmosphere rather than the bulk composition. Detections of several chemical species have been made in a number of sub-Neptunes including H2O, CH4 and CO2. However, different atmosphere-interior interactions could be responsible for this. For example, large amounts of H2O can be produced endogenously via atmosphere-mantle interactions or could have been accreted during formation. This raises the question: can endogenous vs accreted H2O be distinguished observationally? To address this question, we coupled a Global Chemical Equilibrium model with a 1D radiative–convective photochemical atmosphere model to investigate how volatiles are partitioned between the core, mantle and atmosphere. In particular, we test whether

accreted vs endogenous water can be distinguished with atmospheric observations. We find that the abundance of O- and C-bearing species in the upper atmosphere is sensitive to the amount of accreted volatiles, the reactivity of the iron core, and the equilibration temperatures of the interior. For example, a reactive core can store large amounts of O, C and H, “hiding” accreted volatiles from view in the atmosphere. Population studies of sub-Neptune atmospheres may therefore have the potential to provide insights into the role of the iron core in sequestering planetary volatiles. In this talk, I will discuss these trends as well as the implications for the interpretation of JWST observations of sub-Neptunes.

Remo Burn*, K. Bali, C. Dorn, R. Luque, S. L. Grimm*

The interplay of Evolution and Water Sequestration (in person)

An important possibility in core dominated exoplanet evolution is the partitioning of water to the interior of the planets. Here, we investigate the population-level effect of water sequestration to the mantle and metallic core on a population of synthetic sub-Neptunes and super Earths. An estimate of the maximum amount of possible water sequestration is used in the thermal and photoevaporative evolution of the planets. We find the effect on the mass-radius diagram to be significant and predict a metallicity evolution of the atmospheres from low to high with time due to outgassing of water from the mantle with decreasing bottom-of-the-envelope pressure. Qualitatively, the mass-radius distribution of the synthetic planets is well reproduced for planets more massive than three Earth masses.

Simon Cloutier*, Antoine Strugarek, Allan Sacha Brun*

A semi-analytic planetary structure model (in person)

Given input planetary mass and radius (and sometimes composition), planetary structures are typically determined by solving the differential structure equations. Labrosse et al. have shown that by assuming the logarithmic equation of state those equations can be solved approximately. The solutions are a family of analytic profiles for density, gravity, and pressure involving parameters such as the density at the centre of the planet and a compression scale height. These parameters can be easily determined for the Earth using PREM. We show that along mass conservation (input mass of the planet equal to model mass), pressure continuity at layer transitions, and the matching of analytic and EOS pressures yield an algebraic nonlinear system that can be solved for the profile and composition parameters, thereby providing a novel method to solve planetary structures. Having in mind applications of magnetic field generation, we solve for both silicon and oxygen in the core, determine the size of the inner core and its density jump due to change of composition. We also present Ohmic dissipation with its individual contributions, with the thermal model directly making use of the framework of the structure model itself.

David Dahlbüdding*, Tommaso Grassi, Karan Molaverdikhani, Barbara Ercolano, Giulia Roccetti, Dieter Braun, Paola Caselli*

Small Collisions, High Impact: The Sensitivity of the Greenhouse Effect to Collision-Induced Absorption (in person)

Collision-induced absorption (CIA) is a fundamental opacity source in dense planetary atmospheres, playing a pivotal role in determining the heat budget and surface habitability of worlds with high-pressure environments. However, accurate radiative transfer modeling is often limited by the availability of CIA data, which may be outdated, theoretical, or restricted to narrow temperature ranges within current databases. In this talk, we present a systematic assessment of CIA opacities for a wide range of atmospherically relevant molecule pairs — including CO_2, CH_4, N_2, and H_2 — based on currently available experimental and theoretical data from HITRAN. We analyze the relevance of these interactions by computing Rosseland mean opacities across varying temperatures and pressures and comparing CIA contributions against molecular line absorption. To demonstrate the macroscopic impact of these microscopic interactions, we apply our findings to a simple atmospheric model of a tidally heated exomoon orbiting a free-floating planet. In these unique environments, where the energy budget is tightly constrained, the greenhouse effect is a critical driver of potential habitability. We highlight how uncertainties and gaps in current CIA data affects the determination of the habitable zone for these moons, identifying the regions of parameter space where improved laboratory and theoretical data are most urgently needed.

Mark Eberlein*, Ravit Helled*

Evolution of Sub-Neptunes and Neptunes: Importance of the thermal conductivity (in person)

Sub-Neptunes and Neptunes are often modeled under the assumption of an adiabatic interior, that consists of distinct layers. However, formation models and gravity measurements indicate that composition gradients can exist. Such composition gradients inhibit convection. In non-convective layers, the heat transport is governed by multiple processes each relevant in different regions within the planet. This raises the question of how the evolution and internal structure of Neptunes and sub-Neptunes depends on the assumed thermal conductivity. Considering different conductivity models, initial entropies, and masses, the radius evolution over time varies significantly. The inferred radii deviate by up to $\sim$ 20% depending on the assumed conductivity and up to ~25% on the primordial entropy. This emphasizes the importance of these parameters and shows that the theoretical uncertainties are larger than the observed ones. Therefore more data on thermal conductivities, as well as better constraints on the primordial thermal state of Sub-Neptunes and Neptunes are necessary to reduce the theroetical uncertainty.

Jo Ann Egger*, Yann Alibert, Jonas Haldemann*

From BICEPS to plaNETic: A planetary structure model for small exoplanets and its application within the CHEOPS mission (in person)

Over the last thirty years, more than 6000 exoplanets have been discovered, with new planets being announced weekly. Studying the compositions of these planets can give us important insights into planet formation and evolution processes, but requires models capable of accurately describing their interior structures. Here, we present BICEPS, a robust planetary structure model applicable across a wide range of planetary masses, compositions and boundary conditions. Traditionally, such models have been combined with Bayesian inference to explore the range of an observed planet's possible compositions, but this is a computationally expensive and slow process. To overcome this, we developed plaNETic, an open-source framework that accelerates this calculation by replacing the computationally expensive forward model with a neural network as a fast surrogate model. This approach enables a rapid yet reliable inference of a planet’s internal structure, making it well suited for large datasets. The plaNETic framework has already been applied to more than 80 small exoplanets with precise observational mass and radius measurements and is routinely used in publications led by the CHEOPS science team.

Albert Elias-López, *Matteo Cantiello, Daniele Viganò, Fabio del Sordo*

Rossby number, convection, and magnetism in inflated hot Jupiters (in person)

Hot Jupiters (HJs) are often assumed to host the strongest dynamo-generated magnetic fields among exoplanets, potentially up to an order of magnitude stronger than Jupiter’s. Such fields would make them prime targets for detecting magnetic star–planet interactions (SPI) and coherent low-frequency radio emission. However, despite extensive radio and spectroscopic searches, no unambiguous detections have been reported, raising doubts about the realism of the commonly assumed HJ magnetic field strengths. Here, we revisit the internal convection and dynamo properties of HJs using one-dimensional evolutionary models. We explore the dependence on orbital distance, planetary and stellar mass, and on the depth and nature of the heat injection required to explain inflated HJ radii. We show that tidal synchronization is likely valid for all HJs, implying rotation periods close to their orbital periods. Using the resulting interior structures, we compute depth-dependent Rossby numbers to assess whether the dynamo regions remain in the fast-rotator regime ($Ro \lesssim 0.1$), where standard magnetic scaling laws apply. When stellar irradiation is deposited deeply, most HJs maintain low Rossby numbers throughout their convective zones, and classical fast-rotator dynamo scalings recover the strong magnetic fields commonly assumed in radio and SPI studies. In contrast, when heat is injected mainly into the outer envelope—largely outside the dynamo region, as predicted by Ohmic dissipation models—the convective heat flux is strongly reduced. In many cases, parts of the dynamo region cease to convect, leading to magnetic field strengths comparable to or weaker than Jupiter's, possibly governed by different scaling laws. These results challenge the common assumption that inflated HJs necessarily host exceptionally strong magnetic fields and thus doubting detectable radio emission or strong SPI signatures, even with current or near-future instruments.

Yoshi Eschen, *Thomas Wilson*

Exploring the Interior Structures for Planets Around Compositionally Diverse Stars (online)

Planets and stars form from the same proto-stellar material. Hence the stellar refractory elemental abundances are assumed to be strongly linked to rocky planet interiors. This is also found for the refractory elemental abundances of the Sun and Earth. For exoplanets, this compositional link has been recently suggested and explored in small demographic studies. However, the sample of rocky planets around metal-poor stars is limited. This makes it challenging to find and validate potentially vital chemical trends. We developed a novel machine learning approach to identify planet hosting stars of interest to fill in the lack of well-characterised small planets around metal-poor stars. We present newly characterised systems containing Ultra-Short Period Super-Earths and Sub-Neptunes around metal-poor stars of the thick disk. These planetary systems were observed with transit photometry and radial velocity allowing us to measure their radius and masses precisely. We modelled their interior structures for which we further developed tools to link stellar abundances to the core and mantle mass fractions of the planet. These give insights into the elemental abundance ratios of the planets. Hence, we directly study the connection between the planet and host star abundances. These new discoveries significantly add to the sample of rocky planets around thick disk stars and will be followed by further detections and characterisations from our machine learning algorithm. Expanding the sample of well-characterised small exoplanets orbiting compositionally diverse stars enables us to compare different interior structure models to one another. Placing our new and upcoming systems in demographic context, we are now able to further explore the link between stellar refractory elemental abundances and their impact on the interiors of small planets in a larger and more diverse sample. This enables insights into rocky planet formation across the galaxy.

Luke Gauvrit, *Tristan Guillot, Morgan Deal*

Modelling Planets and Stars with CESAM2k20 (in person)

The ESA PLATO mission will provide precise ages and radii for large samples of stars hosting giant planets and sub-Neptunes, enabling statistical studies of their internal structure and formation histories. In parallel, NASA's Juno mission, in polar orbit around Jupiter since 2016, has measured the planet's gravity field with unprecedented precision, revealing a complex interior with compositional gradients and a possible dilute core, which provides a strong benchmark for giant-planet structure and equation of state (EOS) models. To interpret PLATO systems in a physically consistent way, we extend the stellar evolution code CESAM2k20 (already selected to compute the first version of the PLATO grid for the stellar pipeline) so that it can model giant planets within the same framework as their host stars. This is done by implementing modern hydrogen–helium EOS designed for giant-planet interiors together with a linear H/He mixing prescription combined with tabulated non-ideal mixing corrections in density, entropy and internal energy derived from ab-initio mixture calculations. We show that EOSs currently available to model planetary interiors fail to account for the interior structure of the Sun. The parameter domain covering the evolution of M dwarfs, brown dwarfs and giant planets is thus affected by uncertainties probably related to plasma microfield effects as well as interpolation issues. We also present evolution tracks and simulations of interior profiles for stellar and planetary-mass objects computed using the extended capabilities of CESAM2k20. Progress on benchmarking, EOSs, atmospheric boundary conditions and interior opacities are essential for a reliable interpretation of the PLATO results. This work is being developed in collaboration with Tristan Guillot and Morgan Deal within the PLATO WP 116100 framework.

Tristan Guillot*, Saburo Howard, Christoph Mordasini, Ravit Helled, Anna Julia Poser, Nicola Tosi, Marina Cano Amoros, Luke Gauvrit, Ronald Redmer, Simon Müller, Nadine Nettelmann, Lorena Acuña, Solène Ulmer-Moll, Louis Siebenaler*

Benchmarking Giant Planet Interior Models (in person)

In the framework of PLATO's WP116100, we present the first steps toward a benchmarking exercise for giant planet interior models. This effort includes the following evolution codes: CEPAM, CESAM2k20, COMPLETO, GASTLI, MESA, MOGROP, and TATOOINE. Such a comparison is essential for providing reliable estimates of the bulk compositions of the planets that will be discovered by PLATO, and for assessing the robustness of these estimates as a function of planetary parameters. Differences among the codes themselves, as well as in their underlying assumptions (atmospheric boundary conditions, equations of state, opacities), will be examined and discussed.

Claire Guimond

Looking for a relationship between planetary iron content and orbital distance (in person)

The bulk iron content of a planet exerts a first-order control on its interior structure, of fundamental importance to geodynamic processes. Our community is actively trying to quantify the trend between planetary iron content and host star iron abundance, in particular because such a link would evidence a planet-star compositional connection. If planet bulk iron content is also controlled by disk processes, then any other trends would become more complicated to interpret. Across the rocky planets and dwarf planets in the solar system, bulk iron contents correlate with orbital period, possibly explained by the Sun's magnetic field strength (McDonough & Yoshizaki, 2021, PEPS). Compared these solar system bodies, potentially-rocky exoplanets show an even greater spread in bulk density, and hence inferred bulk iron content, which we hypothesise to be explained by not just host star chemistry, but also by orbital distance and/or instellation. In this presentation, I will show our work in progress searching for these trends, and will open the discussion for ways to better understand rocky planet iron content.

Tim Lichtenberg *(Invited)*

Benchmarking time-evolved, coupled interior-atmosphere models of exoplanets

I will describe the organisation and initial results of the CHILI (Coupled atmospHere Interior modeL Intercompariso) intercomparison project, which is part of the CUISINES framework. CHILI benchmarks established models of the time-evolved feedback between interior and atmosphere of rocky planets and exoplanets. The protocol includes two types of test categories, one focused on Solar System planets (Earth & Venus) and the other on exoplanets orbiting low-mass M-dwarfs. CHILI benchmarks aim to quantify the evolution of key markers of the links between planetary atmospheres and interiors over geological timescales. The protocol was worked out at an in-person workshop in autumn 2026 and the intercomparison is in fully swing. I will motivate the necessity for increasing efforts to compare ever-more complex numerical models and why these models are needed for interpreting the increased sensitivity achieved by astronomical surveys.

Zifan Lin*, Sara Seager*

Carbon-rich Sub-Neptune Interiors: Concepts, Structural Models, and Observational Signatures (online)

Many possible interior compositions exist for sub-Neptunes: ice-poor, ice-rich, and water-dominated interiors can all match the measured masses and radii. Motivated by a recent theory of carbon-rich planet formation outside the refractory organic carbon "soot line" and observations of carbon-rich protoplanetary disks around late M dwarfs, we propose another possible sub-Neptune composition: a carbon-rich composition consisting of an iron-silicate core, a carbon layer, and a hydrogen/helium-dominated envelope. We show that the interiors of three prototypical sub-Neptunes with high-quality spectral observations – TOI-270 d, GJ 1214 b, and K2-18 b – are consistent with carbon-rich compositions if they have ≤100 times solar metallicity atmospheres. We further show that carbon-rich interiors lead to atmospheric compositions that match Hubble Space Telescope and JWST observations. Finally, we discuss observational signatures of carbon-rich sub-Neptune interiors and present a roadmap for the future search of such signatures using JWST.

Giulia Martos*, Laura Kreidberg, Lorena Acuña-Aguirre*

An updated mass-metallicity relation for warm giant exoplanets (in person)

Bulk metallicity is a fundamental property of gas giant exoplanets, key to constraining models of planetary formation and evolution. Metal enrichment can be inferred based on mass and radius measurements alone, thanks to the higher densities expected for more metal-rich compositions. Several previous studies of warm Jupiters found a relationship between bulk metallicity and planet mass, consistent with the core accretion model for planet formation. However, these results are based on an inhomogeneous data set with a range of assumptions about the stellar (and thus planetary) parameters. In this work, we revisit the mass-bulk metallicity trend, with a larger sample of planets and improved precision and accuracy for the stellar masses and radii. We combine SED fitting, GAIA DR3 parallaxes, and uniform modeling of the transits and radial velocity measurements using archival data. With updated planet masses and radii, we use the interior structure code GASTLI to infer the metal enrichment of the planets. The improved precision and larger sample enable a test of the intrinsic scatter in the mass-bulk metallicity relation, as well as a search for trends in metal enrichment as a function of stellar type.

Yamila Miguel *(Invited)*, *Louis Siebenaler*

Opacities and their impact on the interior, atmosphere-interior connections and evolution of giant planets

Observations of giant planets increasingly probe their atmospheres across a wide range of wavelengths, revealing molecular abundances, cloud signatures, and thermal structures. Interpreting these measurements requires understanding how radiative transport couples atmospheric processes to the underlying planetary interior. Central to this coupling are opacities, which control how radiation is absorbed and transported, regulate cooling rates, and determine the depth and structure of radiative and convective regions, making them essential for understanding atmosphere–interior connections in giant planets. In this talk, I will provide an overview of the physical processes governed by opacities and present new Planck and Rosseland mean opacity tables spanning a wide range of temperatures, pressures, and metallicities, including the effects of clouds. Using evolutionary models, I will demonstrate how differences in opacity translate directly into observable consequences. These results show that opacities are not merely a modeling detail, but a key ingredient for linking atmospheric observations to the physical and thermal evolution of giant planets.

Francesca Miozzi *(Invited)*

Equations of state and parametrizations, where do they come from and what is the role of experiments.

Equations of state and thermal models have been defined to represent the volumetric changes experienced by materials under increasing pressure and temperature. These tools, extensively used and improved in the years by multiple communities in the broad fields of geology and physics, heavily rely on the experimental capabilities required to produce high quality data. Following the discovery of exoplanets, equations of state have taken an even more prominent role. With mass and radius being the sole parameters that are routinely determined for observed exoplanets, their interpretation often relies on matching the observed density with the value calculated for a synthetic planet of choice. Equations of state, by representing the volumetric change of materials with changing pressure and temperature have a fundamental role in all the models that are used for such calculations. The available wealth of parametrizations describing the behavior in depth or some of the most common minerals and materials has proven to be a great resource for the community. Nevertheless, the widespread use of such tools, and their use for exoplanets, has started to also expose their limitations. For instance, most of the observed planets are bigger than Earth, but there are often intrinsic limitations to available EoSs, as they are valid only at lower pressure due to experimental challenges. Furthermore, multiple EoS are available for the same mineral and frequently use different formalisms. In this presentation, we'll start with a description and analyses of the main formalisms used for equation of state parametrization. We will then move into details of the experimental techniques used to collect the data required for the fit and some of the caveats and common pitfalls of experiments to finish with some perspective on innovations of the field.

Luca Morf, *Ravit Helled*

Icy or rocky? Convective or stable? New interior models of Uranus and Neptune and similar exoplanets (online)

I present a new, bias-minimising framework for modelling the interiors of Uranus and Neptune that unifies empirical flexibility with full physical self-consistency. My method begins with randomized interior density profiles and iteratively couples hydrostatic equilibrium, gravitational harmonics, and equations of state self-consistently. The resulting model ensemble for Uranus and Neptune spans a wide range of compositions permitted by present constraints, revealing that both planets admit rock-dominated and water-dominated interiors. All viable models contain convective ionic-water layers capable of powering their observed multipolar magnetic fields, and none cross hydrogen–helium–water demixing boundaries. Systematic differences also emerge: Uranus tends to host higher H-He fractions in its outermost zones, and its dynamo source region is located deeper relative to Neptune. By demonstrating how wide the physically allowed solution space remains, this work challenges the classical ''ice-giant'' paradigm for these planets and highlights the degeneracies that arise when only low-order gravitational harmonics are available. Furthermore, this is directly relevant for exoplanets: our framework provides an excellent tool set for the large population of intermediate-mass exoplanets. I will discuss how our approach can be extended to exoplanets and how improved constraints from forthcoming missions can systematically narrow the range of viable interior structures.

Vatsal Panwar, *Anna Julia Poser, Lorena Acuna, Matteo Brogi, Anjali Piette, Luke Parker, Siddharth Gandhi*

Investigating the role of atmospheric composition in inflating the lowest density gas-giant (in person)

The radius inflation of highly irradiated gas-giants has been a long standing puzzle for understanding the thermal nature of their interiors and the evolution of these planets. Several mechanisms in the regions ranging from the deep interior to the upper atmosphere, that either add heat (e.g. Ohmic dissipation, tidal heating) or absorb the outgoing radiation and delay a gas-giants cooling (e.g. atmospheric opacity, clouds), have been proposed to explain the phenomena of radius inflation for hot gas-giants. WASP-193b is a recently discovered ultra low-density, hot (equilibrium temperature = 1250 K) gas-giant which shows an extreme level of inflation unexpected for its mature age (~5 Gyr), and is speculated to be an outcome of one or more of these mechanisms. We will present results from our investigation into the role of WASP-193b's atmosphere in sustaining its inflation by measuring the planet's atmospheric composition and thermal structure. Using CRIRES+ on VLT, we measure the high-resolution transmission spectrum of WASP-193b, and detect absorption signatures from CO and water, through which we constrain the planet's metallicity, thermal profile, and cloud properties. We eventually use these constraints on the atmosphere as inputs to thermal evolution models, and quantify the role of the atmosphere behind the extraordinary radius inflation of WASP-193b. We will discuss the outcomes of this study of a gas-giant at the extreme end of the parameter space as observational benchmarks for exoplanet interior modelling frameworks that account for the impact of atmospheric composition and thermal structure.

Anna Julia Poser*, Caroline Dorn*

INFER: A Community Tool for PLATO Interior Structure & Composition Inference (splinter session)

The PLATO INFER Team develops and integrates a community service-tool to rapidly infer the interior structure and composition of exoplanets discovered by PLATO. By combining machine-learning methods with interior models, INFER provides probabilistic, transparent, and reproducible results that complement PLATO's data products and support the broader exoplanet science community. In practice, INFER aims to turn PLATO-level constraints (stellar/planetary parameters with uncertainties) into reproducible interior–composition posteriors across multiple model families. Splinter session: We will give a brief status update on the INFER tool, then use the discussion to decide what should be standardised first (data formats, model outputs) and to clarify how community contributions could work in practice (interfaces, benchmark cases, ...).

Anna Julia Poser*, Heike Rauer*

PLATO: mission overview and what it means for exoplanet interior modelling (in person)

ESA's PLATO mission will characterise a large, homogeneous sample of transiting exoplanets with precise radius, mass, and age measurements, covering planet types from rocky worlds to gas giants at orbital periods largely unexplored by current missions. These constraints will open new windows into interior structure across the full diversity of exoplanets: from magma ocean timescales in terrestrial planets to the radius gap in sub-Neptunes and thermal evolution of giant planets.

We present an overview of the mission status and expected observational yields and highlight the open questions the community is positioned to address in preparation for the mission.

Anjali Piette *(Invited)*

TBD

Wei Qiang*, Tad Komacek*

Convection modelling of sub-Neptunes (in person)

Even though sub-Neptune-like exoplanets are the most common planetary class in the Milky Way, there are open questions regarding their interior structure and processes. JWST and HST observations have shown variations in the atmospheric composition and cloud/haze coverage of sub-Neptunes with temperature, which require more detailed modelling of their interiors. Previous simulations of mixing in sub-Neptune envelopes have shown that convection and the modelled temperature profile of sub-Neptunes are affected by the mean molecular weight gradients in the deep atmosphere. As a result, convection is inhibited and a stable layer forms in the atmosphere when the abundance of condensable species exceeds a critical threshold. Here we reexamine the effect of compositional gradients and convection inhibition on the interior mixing of sub-Neptunes and make interferences on their atmospheric structure and potential presence of a deep stable layer, by developing a bottom-up convection model of sub-Neptune envelopes from the magma ocean interface to the atmosphere, using the Python package Dedalus. This model will be coupled with 3D GCMs to fully link the observations at the top of atmosphere to the interior of sub-Neptunes, and contribute to explaining the observed temperature dependence of mean molecular weight and cloud/haze coverage.

Vanesa Ramirez*, Yamila Miguel, Saburo Howard*

Are Uranus and Neptune really ice giants? (in person)

Although Uranus and Neptune are commonly classified as ice giants, their exact compositions remain poorly constrained. Recent studies of outer Solar System bodies challenge the traditional view that these planets are primarily ice-dominated, suggesting that refractory material may play a more significant role. Determining the proportions of ice and rock within Uranus and Neptune is essential for understanding their formation and the evolutionary history of the Solar System. In this work, we compute interior structure models for both planets and explore, within a Bayesian framework, the range of compositions that satisfy the available observational constraints. We quantify the resulting ice and rock fractions and analyze their impact on the inferred internal structure. We find that the envelopes of both Uranus and Neptune are systematically enriched in refractory material, with median rock fractions of approximately 60% of the heavy-element component, similar to Pluto, Kuiper Belt Objects, and comets. In contrast, their deep interiors exhibit distinct compositions: Neptune is best fit by relatively rock-rich mantles, whereas Uranus favors more ice-rich mantles, consistent with a more strongly stratified structure. These results point to fundamental compositional differences between Uranus and Neptune that may reflect divergent formation and evolutionary pathways.

Yared Reinarz*, Lorena Acuna, Haiyang Wang*

Revisiting the star-planet composition link: a tale of devolatilization (in person)

Rocky exoplanets present diverse compositions and internal structures. Previous work has assumed that the composition of planets is similar to that of their host star. But it is debated whether planets have higher iron to silicon ratios. The apparent iron enrichment has been traditionally explained by mantle stripping or collisions. An alternative explanation is devolatilization of the planetary abundance ratios with respect to the host star, where volatile elements like oxygen and sulfur are progressively depleted relative to refractory elements such as iron and magnesium. In this work, we explore whether these elemental molar ratios are consistent with an Earth-like devolatilization trend. We revisit the estimation of the core mass fraction of 13 rocky exoplanets with masses between 0.5 and 10 Earth masses, focusing on planets where stellar abundances of Fe, Si, Mg, O, and S have already been measured. To conduct this analysis, we use interior structure retrievals with two independent forward models: the Marseille Super-Earth Interior model and ExoInt. These models allow us to estimate compositional parameters, including the molar ratios of iron, magnesium, silicon, oxygen, and sulfur from mass and radius measurements. We find that devolatilization offers a plausible explanation to the observed densities of rocky exoplanets. The variety in trends of refractory elemental ratios, indicate a wide diversity in mantle mineralogies and other properties relevant for habitability, such as mantle solubility. We present a comparison between the 2 models used in this work, and quantify the impact of model differences for the estimation of the devolatilization trend. A main limiting factor in our ability to constrain the relative refractory compositions between rocky planets and their host star is the small sample of rocky exoplanets whose host stellar abundances are constrained and the lack of variety in their orbital distances.

David Rice*, Allona Vazan, Chenliang Huang*

Toward Real Rocky Planet Interiors with Ideal Multicomponent Mixing (in person)

As observational precision improves, a leading uncertainty in exoplanet interior inference is no longer the data but our models of realistic, multicomponent interiors. I present a mixing framework focused on planets less than 10 $M_\oplus$ that treats differentiated layers as chemically consistent mixtures rather than endmembers. We implement this framework in the open-source planet interior code Magrathea. We solve the mineralogy of rocky mantles in closed form from four elemental ratios, Ca/Mg, Si/Mg, Al/Mg, Fe/Mg, using stoichiometric relationships to keep the mantle in chemical equilibrium across upper and lower regions. The resulting phase proportions of Fe–Mg silicates and accessory Ca- and Al-bearing minerals are broadly consistent with mineralogy from Perple_X Gibbs free-energy minimization, but are obtained with a much faster and auditable scheme. We then use ideal mixing to translate these assemblages into density and an adiabatic temperature gradient. We extend the same machinery to tests of light elements in metallic cores, rock–water mixing, and mixed atmosphere species. In each case, we highlight where composition inferences are most sensitive to mixing assumptions. These developments build on the modular equation-of-state and phase-diagram infrastructure of Magrathea v2, enabling reproducible model intercomparisons where differences can be traced to specific materials, phases, and mixing choices rather than hidden defaults.

Frances Rigby*, Nikku Madhusudhan*

Interior Constraints from JWST Spectra: Coupled Atmosphere–Interior Modelling of TOI-270d (in person)

Sub-Neptune planets provide a crucial probe of planetary formation, evolution and potential habitability. The nature of this population remains debated, as the bulk density alone gives rise to degenerate interior compositions. In the era of JWST, data on their atmospheric compositions can begin to alleviate these degeneracies. We explore the possible interior and surface states of a keystone sub-Neptune, TOI-270d, using a coupled atmosphere-interior model incorporating self-consistent atmospheric temperature structures informed by JWST observations. These observations revealed detections of CH_4 and CO_2 in an H_2-rich atmosphere, tentative inferences of H_2O and CS_2, and a notable non-detection of NH_3. This planet, warmer than K2-18b, provides a valuable point of comparison within the growing diversity of sub-Neptunes observed with JWST. The interior solutions permitted by current constraints include mini-Neptune, gas dwarf, and hycean scenarios, with a wide range of surface conditions that are strongly controlled by the atmospheric properties, particularly assumptions regarding clouds and hazes. Our results place new constraints on the potential interior structure and surface conditions of TOI-270d, highlighting the role of theoretical uncertainties in interpreting the nature of sub-Neptunes from their JWST spectra. Improved understanding of atmosphere-interior interactions will be key in refining the surface and interior constraints for TOI-270d.

Emily Sandford*, Yamila Miguel*

The effect of equation of state thermodynamic consistency on simulated planet evolution (in person)

An equation of state (EOS) is thermodynamically consistent if it satisfies the first law of thermodynamics and its derivatives (see e.g. Paxton et al. 2019). Most EOS in widespread use are not perfectly thermodynamically consistent, because other considerations, including fidelity to experiment and smoothness of numerical derivatives, often take priority over thermodynamic consistency. As such, the specific effect of thermodynamic inconsistency on the evolution of stellar or planet models has not yet been evaluated, although it is posited to make structure and evolution models less accurate. Here, we present a procedure for adjusting an EOS table to improve its thermodynamic consistency, based on the work of Timmes & Swesty 2000. We apply this procedure to a set of EOS commonly used for planet modeling: the H/He EOS of Chabrier et al. 2019, with non-ideal mixing terms from Howard & Guillot 2023, and a heavy element EOS based on AQUA H_2O (Haldemann et al. 2020) and SESAME rock (Lyon & Johnson 1992). We show that the adjusted, thermodynamically consistent versions are compatible with experimental Hugioniot measurements, where available. Finally, we compare planet models evolved with (1) the original EOS presented in the literature; (2) thermodynamically consistent versions of the EOS; and (3) "control" versions of the EOS, which have roughly the same thermodynamic consistency as the originals, but deviate roughly as much from the original tabulated values as version (2).

Louis Siebenaler*, Nicole Allard, Yamila Miguel*

Stable stratification in the outer envelopes of giant planets: from the Solar System to exoplanets (in person)

Interior models of giant planets traditionally assume convection as the dominant heat transport mechanism in the molecular hydrogen envelope. However, several observations of Jupiter challenge this picture, including the atmospheric abundances of CO and water and the inferred depth of the zonal winds. One proposed solution to reconcile these observations is a stable layer near the kilobar level. In earlier work, we showed that, when radiative opacities are computed using the impact approximation, such a stable layer in Solar System giants can only be obtained with a strong alkali depletion. In this talk, we present improved opacity calculations based on a unified line shape theory for the alkali (Na/K) resonance lines, which is needed to accurately determine their line widths and wing extents at high pressures. Using these opacities, we reassess the conditions for stable layers in the Solar System giant planets and determine whether stable stratification can persist over their evolution. Finally, we discuss the alkali abundances required for non-convective interiors in giant exoplanets.

Bennett Skinner, *Ralph Pudritz, Ryan Cloutier*

A New Interior Structure Model & The Importance of Solar System Validation (in person)

We present a new hydrostatic interior structure model for application to Earth-like and sub-Neptune planets incorporating the most up-to-date EOS and physical processes. This model includes, among other things, (a) rotation, (b) a radiative transfer-informed temperature profile, and (c) internal luminosity. The EOS used, from uppermost to lowermost layer, include: (1) Envelope: non-ideal mixing between H and He and opacities derived from a Neptune-like super-solar metallicity; (2) Water: the AQUA model; (3) Mantle: the most comprehensive phase diagram for an Earth-like mantle currently available in an interior structure model, with (a) exotic TPa mantle materials such as I42d-type Mg_2SiO_4, (b) equilibrium mineralogy at Earth-like pressures and a mixture of species throughout the mantle, (c) oxide phase and spin transitions, and (d) melting with a composition-dependent melting curve; (4) Core: (a) newly-published thermal terms in the iron EOS, (b) low-pressure solid-solid phase transitions, (c) oxygen and sulphur with partitioning between the liquid and solid cores, (d) melting with a composition-dependent melting curve. We perform a validation step wherein we generate forward models of Mercury, Venus, Earth, the Moon, Mars, and Europa using information from the literature, derived (when possible) from constraints independent of interior structure models (e.g chemical arguments or topography). We compare these forward models to the measured radii and Moments of Inertia (MoI) of these objects, generally achieving errors <0.5%. We highlight the ability to determine the most relevant missing physics by comparisons between forward models and seismology. We advocate for the community-wide adaptation of this validation step, with a particular emphasis on benchmarking on solar system objects beyond Earth and the reporting of MoI. This validation provides a quantifiable measure of theoretical error while avoiding overfitting to a single data point (Earth's radius).

Marie-Luise Steinmeyer, *Caroline Dorn, Aaron Werlen, Simon Grimm*

Identifying atmospheric signatures of sub-Neptune formation location using coupled thermal-chemical evolution models (in person)

The low bulk density of sub-Neptunes suggest that these planets contain a thick layer of volatiles, yet their precise composition remains uncertain. We present a novel evolution framework that incorporates global chemical equilibrium calculations to quantify the effects of the atmosphere-interior coupling on the evolution of sub-Neptunes. This exchange crucially alters the composition of both the interior and atmosphere, yet it is overlooked in commonly used evolution models. Instead, these chemically inactive evolution models assume that all volatiles are confined to the atmosphere of the planet. As a result, the radii of the thick H_2-dominated atmospheres in the gas dwarf scenario are expected to contract significantly as they cool, whereas the radius of water-rich planets remains almost constant over time, suggesting a way to distinguish between these two composition scenarios using the growing sample of sub-Neptunes across different ages. We use our thermal-chemical framework to compare the evolution pathways of a sub-Neptune formed inside the water ice line that accreted only H_2/He, and a sub-Neptune formed outside the water ice line that accreted both H_2/He and H_2O. We find that the radius evolution alone cannot distinguish sub-Neptunes formed inside the water ice line from water-rich planets formed outside of it, when taking the atmosphere-interior coupling into account. Instead, our framework shows how we can use observations of the atmospheric composition of sub-Neptunes by JWST and Ariel to understand the true nature of sub-Neptunes. Particularly the mixing ratio of CH_4 and H_2O and the resulting atmospheric C/O ratio are key tracers of the bulk compositions and formation locations of these planets.

Ankan Sur*, Roberto Tejada Arevalo , Yubo Su , Adam Burrows*
From Compact to Fuzzy: The New Interior Paradigm for Jupiter, Saturn, and Gas Giant Exoplanets (online)
Juno and Cassini have transformed our understanding of the interior structures of the solar system's gas giants. Their gravity measurements reveal that both Jupiter and Saturn likely possess dilute or "fuzzy" cores, rather than the traditional compact ones. This finding has profound implications for how heat and heavy elements are transported within these planets, influencing their thermal evolution, luminosities, and atmospheric metallicities. In this talk, I present the first evolutionary models of Jupiter and Saturn that self-consistently incorporate fuzzy cores, helium rain, ammonia cloud physics, and unified microphysics, successfully reproducing each planet's thermal, compositional, and gravity constraints. I further discuss how these insights extend to gas-giant exoplanets, highlighting differences and similarities with the heritage Sonora Bobcat model suite.

Roberto Tejada Arevalo*, Akash Gupta, Adam Burrows, Donghao Zheng, Yao Tang, Jie Deng*
Sub-Neptune Memories I: Implications of Inefficient Mantle Cooling and Silicate Rain (online)
We explore the evolution of sub-Neptune (radii between ~1.5 and 4 R⨁) exoplanet interior structures using our upgraded planetary evolution code, \texttt{APPLE}, which self-consistently couples the thermal and compositional evolution of the whole structure. We incorporate stably stratified regions with convective mixing and, for the first time, ab initio results on the phase separation of silicate-hydrogen mixtures to model silicate rain in sub-Neptune envelopes. We demonstrate that inefficient mantle cooling can retain sufficient heat to Gyr ages: inefficient heat transport from mantle to envelope alone keeps radii ~10% larger than predicted by adiabatic models at late times. Silicate rain can contribute an additional ~5% to the radius, depending on envelope mass and initial metal abundance. The silicate-hydrogen immiscibility region may lie in the middle or even upper envelope, far above the envelope-mantle boundary layer, and bifurcates the envelope into two an upper, hydrogen-rich region and a lower, metal-rich region above the mantle. If silicate rain occurs, atmospheres should appear depleted of silicates while radii remain inflated at late ages. To demonstrate the effects of inefficient mantle cooling, we present interior evolution models for GJ 1214 b, K2-18 b, TOI-270 d, and TOI-1801 b, showing that hot, liquid silicate mantles with thin envelopes reproduce their radii and mean densities, providing an alternative to water-world interpretations. These results imply that bulk compositions inferred from mean density must account for mantle thermal state and envelope mixing/phase separation history; such thermal "memories" may constrain formation entropies and temperatures when metallicities are better measured.

Daniel Thorngren *(Invited)*
Structure models are the central pillar upon which our understanding of giant planet interiors is built. This review begins with the physics these models are based on, the assumptions and parameterizations that can be used, the various ways they are solved, including a comparison of the ways different groups handle these issues. Next it examines the various observations available for constraining the parameters of these models, as well as the sources of uncertainty, including from the equations of state, structural ambiguities, and observations, by reference to the still-evolving literature. Finally, it will review some of the outstanding questions in the field, such as the differing interpretations of sub-Neptune structure, the degree of layering and central condensation of metals within giant planets, and how chemical interactions may constrain the possible solutions.

Allona Vazan *(Invited)*
From Formation to Observation: Thermal and Structural Evolution of Planetary Interiors
While static interior models provide valuable snapshots of planetary structure, planetary evolution determines how interiors and atmospheres change with time. In this review, I focus on the evolutionary processes that shape planetary interiors across different classes of planets, from gas

giants and sub-Neptunes to super-Earths. I emphasize that planetary age is a key modelling parameter that is often treated implicitly, despite ist strong influence on thermal state, interior structure, and observable properties. In particular, when evolution departs from adiabatic assumptions, formation conditions can influence planetary interiors over long timescales, such that the interior structure at a given age becomes an outcome of the evolutionary history rather than a prescribed input. I discuss why adiabatic interiors represent a convenient but limited approximation, and review physical mechanisms including composition gradients, phase transitions, rainout, and convection inhibition, that naturally lead to non-adiabatic evolution. Importantly, interior evolution is not purely thermal, but involves structural and compositional changes that modify density profiles, heat transport, and material exchange between interior layers over time. These processes affect observed properties such as radius, luminosity, and atmospheric abundances. I conclude by highlighting the implications of evolutionary modelling for interpreting observations and for upcoming missions targeting diverse planetary populations.

Daniele Viganò
Inflated Hot Jupiters have Jovian-like magnetic fields: predictions from long-term evolutionary models with atmospherically-induced Ohmic dissipation (in person)
The inflated radii observed in hundreds of Hot Jupiters (HJs) represents a long-standing open issue, with Ohmic dissipation derived from atmospheric magnetic induction being one of the most promising mechanisms for a quantitative explanation. Using the evolutionary code MESA, we simulate the evolution of irradiated giant planets, spanning the observed range of masses and equilibrium temperatures. We incorporate Ohmic dissipation, accounting for atmospheric induction and realistic profiles of electrical conductivity, and, for the first time, we study how it couples with the dynamo-generated internal field, which is assumed to scale as the internal heat flux as in fully convective stars and Solar planets. We find that, contrarily to the widespread expectations of large magnetic fields in HJs, Ohmic dissipation can partially suppress convection and keep the dynamo-generated magnetic fields at Jovian-like values maximum (few gauss). This has consequence in terms of measurability of atmospheric wind velocities, which depend on the magnetic drag. This talk is based on Viganò et al. 2025, A&A.

Emily Wong*, V. Bourrier, Y. Alibert, Eggenberger, J. A. Egger, C. Dorn, J. Leconte, C. Mordasini, J. Owen, M. Valatsou*
Advancing JADE: Evolution of hot Sub-Neptunes with Water-Enriched Atmospheres (in person)
(TBC) Exoplanets in the hot Neptune desert, with their proximity to host stars and limited envelope masses, challenge our understanding of planetary evolution. Their survival despite expected significant atmospheric loss raises questions about their origins and the mechanisms shaping their fate. To address these complexities, Joining Atmosphere and Dynamics for Exoplanets (JADE) was developed to couple secular orbital evolution (i.e., high-eccentricity migration) with atmospheric loss over long timescales. However, the current version of JADE assumes a pure H/He envelope, which may not fully represent sub-Neptune to Neptune-mass planets, as they likely exhibit higher envelope metallicities and molecular compositions. We now extend JADE by incorporating water into H/He-dominated envelopes, refining opacity, equations of state, and mass loss rates. I will present how these updates enable more realistic simulations of close-in planets' atmospheres, exploring how they bloat or shed their envelopes in response to the intricate dance orchestrated by their host stars and outer companions. We welcome collaborations emerging from this conference.

Paula Wulff*, Hao Cao, Jonathan Aurnou*
Exoplanet magnetic fields: morphology and amplitude (in person)
Planetary magnetic fields mediate star–planet coupling, influence atmospheric escape, and affect the vigour of convection (and thereby heat transfer efficiency). These processes depend not only on the field’s strength but also on its morphology. When assessing rapidly rotating exoplanets it is often

assumed that their magnetic fields are dipole-dominated, mirroring the bias imposed by Earth and other Solar System examples. In this work, we challenge this assumption using a suite of three-dimensional spherical-shell dynamo simulations designed to probe magnetic field generation in non-dipolar regimes. We derive and test new scaling laws that extend classical dipolar formulations to multipolar fields. Our multipolar dynamo simulation results show that while the small-scale magnetic energy follows the same scaling as in dipole-dominated dynamos, the dipole component is systematically weaker - by approximately an order of magnitude - for equivalent control parameters. These findings have significant implications for predicting magnetic signatures of exoplanets, especially in the context of radio detection campaigns and atmospheric escape studies. By providing predictive scaling laws for non-dipolar magnetism, our work broadens the framework for identifying and characterizing exoplanetary magnetic fields.

Li Zeng*, Stephanie Werner, Stein B. Jacobsen*

Water Worlds? Water Worlds! (in person)

Earth might have begun as a water world, but has gradually evolved into a planet with both continents and oceans. Other exoplanets, if they start with more water budget, what would they be? Could they retain that water forever? What are the pieces of evidence from current exoplanet sciences?

Maayan Ziv*, Eli Galanti, Yohai Kaspi*

Characteristic Interior Structures of Jupiter and Saturn Revealed with Machine Learning (online)

Jupiter and Saturn provide complementary observational windows into giant-planet interiors, Jupiter through in situ atmospheric measurements and Juno gravity measurements, and Saturn through Cassini gravity data together with ring seismology, offering a critical Solar-System benchmark for exoplanet studies. Yet, even with these recent highly precise data, inferring interior structures remains a fundamental degenerate inverse problem. To address this, we develop a unified framework that retains the accuracy of the concentric Maclaurin spheroid (CMS) method for computing hydrostatic interior models of rapidly rotating planets, while dramatically improving efficiency using NeuralCMS, a machine-learning surrogate trained on CMS solutions. NeuralCMS enables rapid exploration of broad interior parameter spaces and is coupled to a self-consistent wind model that links the atmosphere and deep interior via wind-induced gravity, allowing atmosphere–interior interactions to be treated consistently. We apply this approach to Jupiter and Saturn under the same modeling assumptions, enabling a like-to-like comparison between the planets. Using clustering analysis on the multidimensional model ensembles, we identify four characteristic classes of interior structures for each planet, reflecting differences in envelope properties and core configuration. We further show that the diversity of solutions can be captured by two effective parameters: one describing the envelope and one describing the deep planetary core. With tighter observational constraints, solutions collapse to one class in each planet, revealing similar architectures yet distinct most-plausible interiors. This work shows that machine learning can accelerate comprehensive, accurate interior modeling and distill it into representative structures and effective parameters, especially valuable for exoplanets, where interior inference is more degenerate given the wider parameter space and fewer measurements.

Esther van Dijk*, Yamila Miguel, Paul Mollière*

The impact of chemically informed atmospheric boundary conditions on hot Jupiter interior retrievals (in person)

Atmospheric boundary conditions play a critical role in interior modeling, as they define the interior adiabat and strongly influence the inferred planetary radius for a given interior structure. For hot Jupiters, their extended and highly irradiated atmospheres enable detailed observational constraints on atmospheric composition, now reaching unprecedented quality with JWST and ground-based instruments. While previous interior structure retrievals have incorporated simplified atmospheric constraints, such as metal enrichment, they rarely include the richer chemical information that is now becoming available. In this talk, we show how atmospheric composition, specifically the metal enrichment ([M/H]) and C/O ratio, informs interior properties of hot Jupiters. We also illustrate how assuming simplified atmospheric compositions, such as a solar C/O ratio, can bias inferred interior properties. We couple a grid of self-consistent 1D radiative-chemical equilibrium models to a static interior structure model. This framework allows atmospheric composition to be used both as an atmospheric boundary condition and as a chemically informed constraint on envelope metallicity. Consistent with previous works, we find that the planetary radius predicted for a given interior structure depends strongly on atmospheric metallicity because of its direct coupling to the envelope metallicity. In addition, we observe a systematic effect from varying the C/O ratio: for a fixed interior structure, higher C/O ratios generally lead to smaller planetary radii. This effect is most pronounced for hotter interiors and therefore particularly relevant for hot Jupiters. By retrieving the interior structure of WASP-19b with different atmospheric boundary conditions, we show that assumptions about atmospheric composition can alter inferred interior properties, highlighting the importance of using chemically informed atmospheric boundary conditions when available.