Galaxies to planets: an elemental journey - Abstract Booklet

Schloss Ringberg, 09.02.2026 - 13.02.2026

Total number of Sessions: 7

Preliminary schedule:					
start time	**Monday 09.02**	**Tuesday 10.02**	**Wednesday 11.02**	**Thursday 12.02**	**Friday 13.02**
9:00	Arrival	Vardan Adibekyan (25+5)	Tobias Buck (15+5)	Giovanni Rosotti (15+5)	Adrien Houge (15+5)
		Allona Vazan (25+5)	Paola Caselli (15+5)	Camille Bergez-Casalou (15+5)	Linn Eriksson (15+5)
		Nicolas Storm (10+5)	Andrea Perdomo Garcia (15+5)	Sofia Savvidou (15+5)	Rafael Luque (15+5)
		Jenny Frediani (10+5)	Kira Lund (10+5)	Mark Eberlein (10+5)	Anastasia Tzouvanou (10+5)
			Joe Williams (10+5)	Yaxing He (10+5)	Leon Hühn (10+5)
10:30		Coffee (30 min)	Coffee (30 min)	Coffee (30 min)	Coffee (30 min)
		Q&A Review talks (50min)	Santi Roca Fabrega (15+5)	Anders Johansen (15+5)	**Discussion 3 (75min)**
		Eric Andersson (15+5)	Inga Kamp (15+5)	Masahiro Ogihara (15+5)	
		Shu-Ichiro Inutsuka (15+5)	Jenny Bergner (15+5)	Wei Zhu (15+5)	
			Luis Welbanks (25+5)	Claudia Danti (10+5)	
				Angelique Kahle (10+5)	
12:30 -14:00	**Lunch (until 13:50)**	**Lunch**	**Lunch**	**Lunch**	**Lunch Boxes**
13:50	Welcome (B. Bitsch + A. Johansen)	**Free afternoon**	Danny Gasman (15+5)	Michael Tremmel (15+5)	**Departure (13:00)**
	Oscar Agertz (25+5)		Ziyan Xu (15+5)	Alice Somigliana (15+5)	
	Chiaki Kobayashi (25+5)		Wlad Lyra (15+5)	Nienke van der Marel (15+5)	
	Ugo Lebreuilly (25+5)		Bertram Bitsch (15+5)	Hubert Klahr (15+5)	
			Henrik Knierim (15+5)	Bibiana Prinoth (15+5)	
15:30	Coffee (30 min)		15:40 Coffe (30 min)	15:40 Coffee (30 min)	
	Haiyang Wang (25+5)		Lorena Acuna (15+5)		
	Catherine Walsh (25+5)		**Discussion 1 (90min)**	**Discussion 2 (120 min)**	
	Gijs Mulders (25+5)		**Leader: Th. Henning**		
	Andre Izidoro (25+5)	**17:30-18:30 Castle tour**			
	Quick intro round (15min)				
18:30-20:00	**Dinner**	**Dinner**	**Dinner (Bavarian Evening)**	**Dinner**	

Chairs:

Monday Afternoon	Bertram Bitsch
Tuesday Morning	Anders Johansen
Tuesday Afternoon	Camille Bergez-Casalou + Sofia Savvidou
Wednesday Morning	Giovanni Rosotti
Thursday Morning	Linn Erkisson + Anastasia Tzouvanou
Thursday Afternoon	Catherine Walsh
Friday Morning	Michael Tremmel

Topics:

Galaxies
Stars and Star formation
Protoplanetary discs
Planet formation
Exoplanets
Discussion

Poster presentations:

Camila Koshikumo

Global HD simulations of giant planet-disk interaction

In the context of giant planet formation, one of the main theories is the core accretion scenario, in which most of the mass is accreted onto the planet in the runaway gas accretion phase. However, the processes occurring in this phase are not yet fully understood. In this work, we aim to study mass accretion onto a Jupiter-mass planet embedded in a disk at a radius of 4 AU. To achieve that, we employed 3D global hydrodynamical simulations with mesh refinement using the GPU-accelerated code gPLUTO. We successfully observed the formation of a circumplanetary disk around the planet and obtained a small accretion rate, which is expected given that there's no viscosity acting to replenish the mass in the gap in our setup. In order to obtain more realistic accretion rates, the next step will be to use magneto-hydrodynamic simulations and include the vertical shear instability.

Oral presentations:

Oscar Agertz
Formation of Galaxies
In this review talk, I will provide an overview of galaxy formation and evolution, with a particular emphasis on insights from theoretical models and numerical simulations. I will highlight key physical processes that shape galaxies and show how a deeper understanding of feedback from massive stars has been crucial for addressing long-standing problems, including the origins of galaxy masses, sizes, and angular momenta. The crucial connection between star formation and the cosmological cycling of gas will be emphasized, particularly in how it influences the chemical composition of stellar populations in galaxies. Finally, I will discuss current challenges and future directions in galaxy formation modeling, highlighting areas where theoretical predictions and observations remain in tension and where key physical processes may still be missing.

Chiaki Kobayashi
Elemental Production in Galaxies
Explaining the origin of the elements is one of the scientific triumphs linking nuclear physics with astrophysics. During the Big Bang, only light elements such as hydrogen and helium were produced. Carbon and heavier elements (called metals in astronomy) are created inside stars and are ejected when they die. Iron-peak and neutron-capture elements are further produced by binaries - Type Ia supernovae and neutron star mergers, respectively. Elemental abundances of stars, together with kinematics from the Gaia satellite, have been extremely useful for constraining stellar astrophysics, as well as the star formation and chemical enrichment history of the Galaxy. This approach, Galactic Archaeology, can now be applied to external galaxies thanks to spectroscopic surveys of galaxies across cosmic time, particularly with the James Webb Space Telescope (JWST). JWST was expected to find the first galaxies - those hosting metal-free (known as Pop III) stars. Surprisingly, though, galaxies with strong metal lines have been detected indicating unusual chemical composition (e.g. high N/O ratio). To understand these observations, my team has been running hydrodynamical simulations following detailed chemical evolution from cosmological initial conditions. The observed high N/O ratios might indicate the existence of very or super massive stars linking to the origin of super-massive black holes. However, the observation can naturally be explained with Wolf-Rayet stars under intermittent star formation, which is also consistent with other elements (F and Ar) observed in distant galaxies. Therefore, the origin of the first metals observed is 10-100Mun massive stars.

Ugo Lebreuilly
Formation of Stars and their protoplanetary discs
Stars and their planet-forming discs form through the gravity-driven collapse of cold, dense, magnetised regions within molecular clouds of the interstellar medium. Since the pioneering theoretical studies of the 1960s, our understanding of this process has evolved substantially. In this review talk, I will highlight insights from state-of-the-art numerical simulations that challenge the traditional sequential picture of star, disc, and planet formation. By following the coupled dynamics of gas and dust and accounting for environmental effects, these models reveal how young, embedded star-disc systems are shaped from their earliest stages, shifting the timeline for the emergence of the first planetary seeds.

Vardan Adibekyan
Measurement of stellar abundances and its connection to planet formation
Stars and planets emerge together from the same primordial material, shaping and reshaping one another through a variety of interconnected processes. Stellar radiation governs the evolution of protoplanetary disks and thereby planet formation, while, conversely, processes such as planet engulfment

can leave measurable chemical fingerprints on stellar atmospheres. Because protoplanetary disks dissipate within just a few million years-well before most planets can be detected-stellar atmospheres provide the only long-lived record of the disk's original chemistry. I can review the compositional link between stars and planets, emphasizing how stellar abundances inform our understanding of planetary formation and interior composition.

Catherine Walsh

Protoplanetary disc structure and composition in the era of ALMA and JWST

In this review talk I will give an overview of the structure and composition of planet-forming disks. I will present observations in support of our understanding including the compendium of new findings revealed by ALMA over the past 15 years, and key results from ALMA Large Programs (e.g., DSHARP, MAPS, exoALMA, and DECO). I will also give an overview of recent results from JWST which allow us, for the first time, to measure the composition of the inner regions at high spectral resolution.

Gijs Mulders

Exoplanet demographics

Exoplanets are a diverse population. The more than 6000 known exoplanets different greatly in their masses, sizes, orbital periods, and even the type of stars they orbit. There is, however, also order in this chaos, with certain type of planets and planetary systems occurring more frequently than others. By correcting for the biases inherent to different exoplanet detection methods, the demographics of planets orbiting other stars can be constructed. In this review I will paint a picture of exoplanet demographics consisting of two main populations: The first is a population of (ice) giant planets that extends over orders of magnitude in star-planet separation. These planets are detected by radial velocity, micro-lensing, direct imaging, and transit surveys. Their planet host stars tend to be more massive and more metal rich. The second is a population of planetary systems containing super-earths and sub-Neptunes detected by transit and radial velocity surveys. Our observational view of these systems is limited to within 1 astronomical unit from their host stars. Still, they orbit an estimated 50% of sun-like stars, and are also frequently found around stars that are in low in mass or metal poor.

Andre Izidoro

Formation of planetary systems

Haiyang Wang

Star-Planet Chemical Connections: From Stellar Abundances to Rocky Planetary Composition and Habitability

Chemical connections between stars and their planets - as revealed through Solar System data and exoplanetary inferences such as spectroscopic measurements of polluted white dwarfs and planet engulfment events - are crucial for understanding how planetary systems form, evolve, and diversify. Stellar elemental abundances set the initial chemical boundary conditions of protoplanetary discs, yet the extent to which these compositions are inherited, modified, or erased during planet formation remains an open question, particularly for rocky worlds. In this talk, I place recent progress on star-planet chemical connections within a broader context spanning stellar abundance measurements, planet formation, and cosmochemistry. I focus on how elemental signatures - particularly the systematic depletion of volatiles (i.e. devolatilization) relative to their host stars - encode information about the physical and chemical processes of planet formation. Using Earth and Mars as anchor points, I demonstrate, within an inverse, probabilistic framework, that volatile depletion can be treated not merely as a compositional outcome, but as a diagnostic fingerprint of planet formation pathways, reflecting the relative roles of planetesimal formation, pebble accretion, and giant impacts.

I conclude by outlining a set of open questions and emerging observations that can drive future studies of the compositional links between stars, discs and planets, with implications for exoplanetary habitability and the origin of life.

Allona Vazan

Planetary interiors and their relation to their upper atmospheres

Planetary atmospheres carry important clues about planet formation and evolution, but understanding their observed diversity requires going beyond the simple link between bulk composition, formation environment, and present-day atmospheric properties. In this review, I will discuss how interior chemistry and thermodynamics play a central role in shaping atmospheric composition over time. Material interactions, phase changes, and chemical reactions deep inside planets can redistribute elements, store or release volatiles, and even produce new compounds, altering what ultimately reaches the atmosphere. As a result, the atmospheric composition we observe today may differ significantly from the material inventory established during formation. I will highlight recent advances in theory and experiments that reveal the importance of interior processes for interpreting atmospheric observations, and outline key open questions in linking planetary interiors to their upper atmospheres.

Luis Welbanks

Exoplanet atmospheres

Eric Andersson

Chemical enrichment in the first galaxies

I will present my work focusing on chemical enrichment in the early Universe. Specifically, the signatures from the first stars (Population III), and how enriched material mixes inside, is ejected from, and transferred between the first galaxies. These processes imprint signatures in the abundances of the stars that form during this epoch, some of which are observable today. Using this information, we can predict when heavy elements became abundant in the Universe, an important step for the earliest sites of planet formation.

Shu-Ichiro Inutsuka

Bubble-Filament Paradigm of Star Formation and Its Implication for Planet Formation

I will try to explain the initial conditions of planet formation, i.e., how the protoplanetary disks are created around a new-born star in the context of bubble-filament paradigm of star formation.

Santi Roca Fabrega

Tracing the galactic star formation rates with lithium and the potential effect of planets engulfment

In this talk I will present our results on the origin of the lithium abundance distribution in Milky Way thin-disk dwarf stars, and how it can be used as an additional tracer of the Galactic star formation history. Using a large sample of FGK main-sequence stars, we confirm that their photospheric lithium abundances display a clear bi-modal structure, with two well-defined populations connected through a low-density "isthmus" region. We show that this feature is not a statistical artefact, but instead can be naturally reproduced when stellar lithium depletion is combined with a non-smooth, bursty star formation history in a Galactic chemical evolution model that includes the main known lithium production channels. Our results indicate that the timing and relative strength of star formation episodes leave measurable imprints on the present-day lithium distribution, providing a new, independent way to constrain the recent star formation history of the Milky Way. Finally, I will discuss how these conclusions connect with star-planet interactions, and in particular how planet engulfment events could act as a secondary mechanism able to locally enhance stellar surface lithium, potentially contributing to the observed scatter and to outliers within the global Galactic trend.

Inga Kamp

Estimating elemental abundances in disks using JWST and ALMA

Our understanding of planet formation has changed recently, embracing the new idea of pebble accretion. This means that the influx of pebbles from the outer regions of planet-forming disks to their inner zones together with diffusion and collisional mixing processes could influence the composition of the building blocks of planets. This could then further propagate into the composition of planets and their atmospheres. The solid and molecular components delivered to the planet-forming region can be best characterized by mid-infrared spectroscopy. Due do the sensitivity and spectral resolution provided by JWST we now have a unique tool to obtain the full inventory of chemistry in the inner disks of solar-types stars, Very Low Mass stars and brown dwarfs, including also less abundant hydrocarbons and isotopologues. I will present results of the MINDS (MIRI mid-INfrared Disk Survey, PI: Th. Henning) survey, connect them to thermo-chemical disk models and transport models and discuss how this informs our understanding of transport and mixing processes in young planet forming disks.

Jenny Bergner

The icy composition of planet-forming solids

Planets are born from the gas, dust, and ice present within the disks around young stars. The icy component of the parent disk is profoundly important to the outcomes of planet formation, but prior to JWST there were virtually no observational constraints on ices in disks. In this talk, I will describe our recent progress in revealing the icy landscape of protoplanetary disks, using JWST in tandem with new simulation frameworks and lab experiments. I will highlight how these efforts are informing our understanding of the volatile composition of exoplanet building blocks, and the formation and behavior of icy planetesimals within and beyond our solar system.

Jenny Frediani

Extreme UV Environments (XUE): the role of external irradiation on planet-forming disks

Most stars and planetary systems form in dense and massive star clusters, where the protostellar systems are exposed to strong far-ultraviolet (FUV) radiation originating from nearby massive stars of spectral type O and B. The external photoevaporation process induced by FUV photons dominates the dispersal of planet-forming disks in high mass star forming regions, producing a rapid outside-in loss of gas and dust that canÂ alterÂ the assembling of planets.Â With the advent of the James Webb Space Telescope (JWST), it is now possible to extend the investigation of the physical and chemical properties of planet-forming environments, particularly of the terrestrial planet-forming region, to massive clusters located at kpc scales.Â As part of the XUE collaboration, this talkÂ will focus on the latest findings on a sample of 12 externally irradiated disks observed with JWST in NGC 6357. This will include the unusual CO2-rich and H2O-poor inner disk surrounding an intermediate-mass star (Herbig), andÂ the modelling efforts with ProDiMo to explain the JWSTÂ observations ofÂ disksÂ in different environments.

Nicolas Storm

The 4MOST S4 survey and Stellar Spectroscopy for PLATO

The 4MOST S4 survey (PIs: Thomas Bensby and Maria Bergemann) will deliver near-complete spectroscopic coverage of the PLATO long-pointing southern field, providing a rich dataset for stellar and exoplanet host characterisation. The survey will yield precise chemical abundances, radial velocities, and stellar ages for a large and homogeneous stellar sample, enabling detailed studies of Galactic evolution and planet-host correlations. In this talk, I will give a brief overview of the S4 survey and its exoplanet subsurvey, and then focus on my contribution to the development of the artificial neural network used in the S4 stellar-analysis pipeline.

Danny Gasman

CO_2 in the context of inner disk enhancement due to drifting ices

The enhancement of H_2O in the inner disk due to drifting icy pebbles is currently a hot topic. However, dust may not only bring in water-ice, but other ice species as well. In fact, trapping of ices in water-ice may prevent specific species from sublimating at their own snowline. This may have implications for the formation and composition of terrestrial planets. The CO_2 snowline is relatively close-in too, and we may be able to trace CO_2 sublimation using JWST-MIRI.

Ziyan Xu

Pebble Accretion and Volatile Transport in Convective Envelopes of Protoplanets

Pebble accretion is one of the leading theories of planet formation, providing an efficient pathway for growing planetary cores by accreting mm-cm sized solids. The efficiency of this process, the fate of the pebbles, and volatiles they carry within protoplanetary gas envelopes, are key to understanding the formation and composition of terrestrial planets. We study how convection within planetary envelopes influences both solid accretion and volatile transport using 3D hydrodynamic simulations with Athena++. The envelope is modeled as fully convective, driven by pebble accretion heating, with Lagrangian particles representing solids or volatiles. Our results show that pebble accretion remains efficient when particles are large enough, corresponding to Stokes numbers above about 0.001 in the disk, which allows them to settle through convective upflows. When the Stokes number is smaller, convection efficiently mix pebbles outward, leading to their recycling back to the disk. These small grains being recycled are likely the main carriers of most volatile materials, leading to rapid volatile loss from the envelope. The sensitivity of accretion efficiency to the Stokes number implies that processes affecting it, such as the choice of drag law and dust growth or fragmentation, can strongly influence accretion outcomes. Overall, our results show that convection acts as a selective filter, allowing solid accretion while driving volatile depletion. This links pebble accretion dynamics to the chemical evolution of forming planets and provides new insight into how terrestrial planets acquire their present-day compositions, as well as the volatile depletion detected in Earth and Mars.

Wlad Lyra

Polydisperse pebble accretion: lessons from the Kuiper belt

The Kuiper Belt stands as the only location in the Universe where pristine planetesimals are accessible to local direct study. In deep freeze beyond the orbit of Neptune, Kuiper Belt Objects (KBOs) preserve a record of how solids accumulated in the early Solar System, offering key tests for planet formation theory. One particularly striking trend is seen in the densities of these objects: larger KBOs are up to five times denser than smaller ones, a dichotomy difficult to explain under the usual assumption of constant composition and collisional growth. In this talk, I will show how this trend can be explained by formation models based on streaming instability and pebble accretion. I will present planetesimal formation simulations tracking ice and rock fractions, and a major update on the theory of pebble accretion by including a continuous multi-species (polydisperse) distribution of grain sizes. Accretion rates of low-mass objects rise by up to two orders of magnitude compared to single-species accretion, thus eliminating the need for a long phase of collisional growth. Our model reproduces the observed density-mass relation of KBOs, also constraining the formation of the higher-mass objects to the region around 20AU. Finally, the observed distribution of KBO binaries reveals a gap in the range between 1e19-1e20 kg, coinciding with the truncation in the initial mass function of planetesimals seen in simulations. Together, these results link KBO densities, growth timescales, and architecture into a consistent picture of formation by streaming instability and growth by pebble accretion, mechanisms that likely universally shape planet formation.

Bertram Bitsch

New ways to constrain the origin of giant planets

Planet formation simulations require a large set of input parameters regarding the disc properties (e.g. mass, radius, turbulence), whereas planetary observations only provide a handful of constraints (e.g. mass, orbital distance, atmospheric composition). In this talk, I will show the results of large set of planet formation simulations and discuss their statistical implications for the formation and composition of planets. I will then discuss a new idea to constrain the formation location of these giant planets, related to their total heavy element content.

Henrik Knierim

Unraveling the origin of giant exoplanets

Gas giant planets are central to our understanding of planetary systems. While high-precision atmospheric data from facilities like JWST are now available, linking these observations to a planet's formation history remains a challenge. Traditionally, atmospheric abundances are interpreted using simplified interior models, such as a distinct core and a homogeneous envelope. However, missions like Juno have revealed that giant planet interiors are far more complex, likely featuring composition gradients ("dilute cores") and superadiabatic regions. In this talk, I will discuss how the internal structures of gas giants evolve with time and how these processes influence the observable properties of their atmospheres. Using advanced evolution simulations and analytical models, we explore the interplay between primordial composition gradients and entropy in shaping a planet's evolution. I will highlight why mixing processes are particularly critical during the early stages of planetary evolution and how the internal conditions of a planet can sometimes "hide" its true bulk composition.

Lorena Acuna

WASP-80 b's precise heavy element content revealed by joint interior-atmosphere retrievals

Warm gas giants with low densities present a unique opportunity to constrain their bulk metal mass fractions and atmospheric compositions, offering insights into their formation pathways. WASP-80 b is one such exoplanet, with panchromatic spectra from JWST and HST in both transmission (0.5-4 μm) and emission (1-12 μm), along with precise mass and age measurements. In this talk I will present how joint interior-atmosphere retrievals can be used to derive precise constraints on the planet's bulk metal mass fraction, atmospheric composition and thermal structure. I will also discuss how joint retrievals can resolve discrepancies between traditional atmospheric retrievals and bulk density constraints, improve the precision of bulk metal mass fraction estimates by a factor of two when combined with precise stellar ages, and uncover degeneracies between interior structure and atmospheric chemistry.

Tobias Buck

Galactic Alchemy with AI: Chemical Evolution through Simulations and Machine Learning

Understanding the chemical evolution of galaxies is essential for connecting the cosmic context of star formation to the conditions that ultimately shape planetary systems. In this talk, I will present new results from the NIHAO-UHD cosmological hydrodynamical simulations, which incorporate an extended implementation of galactic chemical evolution and astrochemistry. These simulations provide a high-resolution view of how stars and gas interact to build up the chemical reservoirs that future generations of stars and planets inherit. I will then discuss how simulation-based inference (SBI), powered by modern machine-learning methods such as transformer-based diffusion models, enables us to infer key galactic parameters - such as star formation efficiencies, feedback processes, and empirical yield tables - directly from observations. Finally, I will introduce COMPASS, a new framework for model comparison that allows us to rigorously evaluate competing prescriptions of astrochemistry and stellar yields. By combining high-resolution simulations with flexible inference and model - comparison tools, we can begin to bridge small and large scales- linking galactic evolution to the chemical environments in which planets form. In the spirit of this workshop, I will highlight open questions and potential synergies between galaxy-scale chemical evolution, planet-formation models, and data-driven approaches, with the goal of fostering discussion and collaboration across disciplines.

Paola Caselli

From clouds to planets: the astrochemical link
All the ingredients for forming stars, planets, and life are found in dense, cold interstellar clouds called prestellar cores. At these early stages of star formation, organic molecules thrive, and dust grains grow thick icy mantles, where water and organics accumulate. Knowledge of the chemical and physical structures of prestellar cores and surrounding clouds is needed to provide the initial conditions for star and planet formation. Here, I present a journey that follows the evolution of prestellar cores toward the formation of stellar systems like our own, and show the crucial role of astrochemistry as a powerful diagnostic tool for the various steps along the journey.

Andrea Perdomo Garcia

Planet formation theory under the gaze of Z metallicity: unexplained planets
We explore the metallicity Z of exoplanet host stars, using new chemical composition data for planet host stars from large-scale stellar surveys. The distribution of planet-hosts with Z are compared to the predictions of planet formation models: core accretion (CA) and gravitational instability (GI). We find that approximately 15.7% of the planets are formed under the conditions predicted by both CA and GI, 0.4% only by GI, and 82.9% only by CA. There are six planets orbiting five stars, which cannot be explained by any theory. We identify the search of exoplanets in relatively metal-poor hosts and large surveys that consistently chemically characterize exoplanet hosts as the key pieces needed to solve the puzzle of planet formation.

Kira Lund

The cosmic journey of dust grains
Dust is essential to the evolution of galaxies and drives the formation of planetary systems. The challenge of inferring the origin of different presolar dust grains from meteoritic samples motivates forward modelling to understand the contributions of low- and high-mass stars to dust in our Solar System. In this talk, I will present the results obtained by comparing the evolution of AGB and supernova dust in a hydrodynamical simulation of a Milky Way-like isolated disc galaxy. Our findings and particularly their implications for the Solar System budget of short-lived radioactive isotopes such as 26Al, whose decay contributed to melting and differentiating planetesimals, highlight the necessity of considering the evolution of dust in a galactic setting, as well as bridging the gap between the scales of galaxies and planetary systems.

Joe Williams

Pebble Drift and Volatile Entrapment: Impact on Planet Formation Chemistry
Chemical models of protoplanetary discs and planet formation by pebble accretion typically assume layered, unmixed ice layers atop growing and drifting pebbles. Recent JWST observations indicate that volatile species (e.g. CO, CO2) can be locked inside water ice in the planet-forming environment; laboratory experiments of ice formation and inferences from new high-resolution ALMA observations also reveal such mixing. We present the first 1D chemical transport model that couples pebble drift and the entrapment of CO inside water ice, representing a significant change in the way that CO and carbon is distributed throughout protoplanetary discs. Our models demonstrate significantly boosted C/O and C/H ratios - up to a factor of 10 - particularly in young (< 2 Myr) discs, which may inherit most of their ice from the interstellar medium. This may generate discs that are simultaneously carbon- and water-rich, observable with JWST. We finally speculate on the chemical inventory of forming planets impacted by volatile entrapment: they have access to up to 50% more heavy elements in the gas-phase and significantly more carbon inside 1 au, and can access otherwise-inaccessible solid-phase CO.

Giovanni Rosotti

Dust and turbulence in proto-planetary discs
I will present recent constraints on the level of turbulence in proto-planetary discs and discuss how

this impacts dust evolution and growth on the way to planets, highlighting in particular the open issues in understanding how effective dust traps are in blocking radial drift

Camille Bergez-Casalou

The peculiar composition of disks around very-low-mass stars

Recent MIRI/JWST observations of disks around very-low-mass stars (VLMS) tend to show that these disks are rich in hydrocarbons compared to their TTauri homologs. The origin of the carbon-rich chemistry is still debated, but can be linked to the characteristics of the VLMS (e.g., small disks, low accretors). In this context, I will present NIRSpec observations of two VLMS disks, where the hydrocarbons are missing. I will discuss the different possible scenari explaining this descrepancies, still in comparison with TTauri disks.

Sofia Savvidou

Is the inner disk composition regulated by the disk and stellar properties or the existence of substructures?

Prior studies have shown that the chemical composition of the inner protoplanetary disk can be shaped by the inward transport of solids from the outer disk, with volatiles evaporating at their individual icelines and enriching the inner disk gas. Recent JWST observations have also revealed enhanced water abundances in compact, smooth disks compared to extended substructured ones, consistent with efficient volatile delivery by pebble drift in smooth disks. On the other hand, substructures, such as pressure bumps and gaps, could regulate this radial transport by trapping the inwardly drifting dust. The variations in the observed inner disk compositions are often attributed to the disk or stellar properties, however, we aim to determine how strongly these differences are instead shaped by the presence of (even undetected) substructures. We perform numerical simulations probing various stellar masses from 0.1 to 1.3 solar masses to investigate the influence of the stellar properties, varying the disk size, along with the gap depth, the timing for the introduction of the gap, and α-viscosity which affects the accretion rates.

Mark Eberlein

Thermal evolution of intermediate size planets: Importance of the thermal conductivity

In non-convective layers, the heat transport is governed by multiple processes, each relevant in different regions within the planet. This raises the questions of how the evolution of Neptunes and sub-Neptunes is affected when considering nonconvective layers and the sensitivity of the results to the assumed thermal conductivity. Considering different conductivity models, initial entropies, and masses, the radius evolution over time can vary significantly. Especially it can affect the regions, that are stable against convection and therefore the distribution of heavy elements within the planet. This shows that furthere work on the thermal conductivity is necessary as well as more constraints on post-formation entropies of Neptunes and Sub-Neptunes, to reliably connect radius, mass, and the interior over time.

Yaxing He

Linking the atmospheric composition to the migration history of hot Jupiters

Atmospheric abundances of exoplanets are thought to constrain planet formation pathways. In this work, we couple a disk evolution model that includes pebble growth, drift, thermal decomposition of refractory organics, and CO entrapment in water ice with a planet formation model that incorporates pebble and gas accretion as well as planet migration to compute the atmospheric compositions of giant planets. We focus on matching the atmospheric abundance constraints of nine observed hot Jupiters. By utilizing stellar abundances and varying the disk viscosity and initial planetary position, we aim to reproduce the observed C/H and O/H ratios for each target. Our results show that the majority of these hot Jupiters originated beyond the water ice line. Based on these constrained parameters, we further compare the planets' final positions driven by disk migration with their currently observed orbital distances. We find that planets for which the simulated final positions match the observed positions tend to exhibit low obliquities, whereas planets that stall farther out in the simulations than observed tend to exhibit high obliquities, which is consistent with late-stage scattering. Our model thus allows for a self-consistent prediction of the dynamical history of hot Jupiters based on their atmospheric chemistry.

Anders Johansen

Planetary population synthesis including water and carbon composition

The streaming instability and pebble accretion are two physical mechanisms with demonstrated potentials to drive, respectively, the formation of planetesimals and the growth of planetary systems containing a diverse range of planetary types. However, the degree to which these mechanisms thrive depends on a number of relatively weakly constrained parameters relating to the gas and pebbles in the protoplanetary disc as well as the composition of the host star. Here we explore the protoplanetary disc conditions in terms of turbulence strength, initial disc size, accretion viscosity, Stokes number and metallicity that are needed to (i) form planetesimals by the streaming instability, (ii) form gas giant planets in distant orbits, (iii) form super-Earths and sub-Neptunes close to the star and (iv) form rocky planet embryos in temperate orbits.

Masahiro Ogihara

Planet formation simulations and the origins of planetary compositions

Planet formation simulations are being used to understand how planetary compositions are established. In this talk, I will introduce some studies that focus on the physical processes that shape planetary compositions. I will first show how models of protoplanetary disks, particularly their structure and evolution, influence planet formation, and present recent developments in disk modeling carried out by our group. I will then discuss how planet formation simulations can be used to investigate planetary compositions, highlighting our studies on the relationship between disk metallicity and the properties of the resulting planetary systems, as well as on the physical processes that can explain the observed compositions of planets.

Wei Zhu

Planetary shape and spin as new observables to constrain their formation and evolution

Due to their rapid rotation, Jupiter and Saturn in the solar system are oblate in shape, with the equatorial radii larger than their polar radii. Similarly, exoplanets can (and are expected) also become oblate due to fast rotations. For exoplanets that transit their host stars, their shape and obliquity can be measured/constrained by the precise transit light curves. In this talk, I will introduce the principles and technical requirements for constraining the shape and rotation of exoplanets using the transit method, and present some interesting and ongoing works based on data from the James Webb Space Telescope.

Claudia Danti

Super-Earth formation in systems with cold giants

Around our Sun, terrestrial planets did not grow beyond Earth in mass, while super-Earths are found to orbit approximately every other solar-like star. It remains unclear what divides these super-Earth systems from those that form terrestrial planets, and what role wide-orbit gas giants play in this process. Here, we show that the key uncertainty is the degree of viscous heating in the inner disc, which regulates the pebble accretion efficiency. In this parameter study, we assume pebble sizes limited by fragmentation and radial drift. The initial seed planetesimals for embryo growth are taken from the top of the streaming instability mass distribution. We then evaluate the important role of the pebble scale height and the assumed pebble fragmentation velocity. In systems with maximally efficient viscous heating, where all the accretion heating is deposited in the disc midplane, pebble accretion in the terrestrial region is suppressed. More realistic levels of viscous heating, at higher elevations, allow terrestrial embryo formation at Earth-like orbits. We also find that the role of the water iceline is minor, unless it is paired with extreme volatile loss and a change in the pebble fragmentation velocity. Furthermore, we show that in systems with gas-giant formation, the role of mutual pebble filtering by outer pebble-accreting embryos is limited, unless some mechanism of delaying inner disc growth, such as viscous heating or the presence of an iceline, is simultaneously employed. This latter point appears to be consistent with the fact that no strong suppression is seen in the occurrence rate of super-Earths in systems with known gas giants in wider orbits. We conclude that the diversity in inner-disc systems may largely be driven by complex, and as of yet poorly understood, disc accretion physics inside the water ice line.

Angelique Kahle

What refractory molecules in ultra-hot Jupiters can teach us about planet formation and evolution

To benchmark planet formation theories, comparing their predicted outcomes to the existing population of exoplanets is crucial. Today, high-sensitivity facilities like the VLT and JWST allow us to establish molecular inventories for a plethora of different planets. While space-based observations detect plenty of volatile species, such as CO, H2O, CH4, and CO2, the detection of refractory species remains almost exclusive to ground-based facilities. This separation limits the comparability of measured inventories of refractory and volatile species. The absence of a reliable refractory-to-volatile ratio is a major challenge for constraining planet formation and evolution models, as the C/O ratios commonly used to trace formation scenarios can be reproduced by various processes. Ultra-hot Jupiters provide an opportunity to simultaneously measure refractory and volatile species in exoplanet atmospheres: As the hot temperatures on their tidally-locked daysides prevent silicates from condensing out, we can use JWST to measure SiO in their gas phase. By observing the 0.6-12micrometer dayside emission spectrum of the ultra-hot Jupiter WASP-121 b, we establish inventories of volatile and refractory species on the planet. This contribution will present the methods used and discuss the results and their implications on planet formation and evolution in the WASP-121 system.

Michael Tremmel

The Role of Feedback in Transporting Heavy Elements in Galaxies

I will present results from cosmological hydrodynamic simulations showing the important role that feedback, in particular from massive black holes, in transporting heavy elements throughout the galaxy and the surrounding circumgalactic medium. I will discuss this in the context of the galactic fountain and how this impacts the evolution of the overall metal content within galaxies.

Alice Somigliana

The JWST/MIRI view of the binary system HK Tau

The binary system HK Tau is composed of a face-on primary and edge-on secondary disc-bearing stars; this offers a unique opportunity to investigate the spectral features in multiple stellar systems, as the complementary inclination of the two sources allows the simultaneous exploration of both the gaseous and icy state chemistry. In this talk, I present the results obtained from the spectral analysis of the JWST/MIRI observations of both HK Tau A and B. In line with other known binary systems, the primary star shows a line-rich spectrum, while HK Tau B is stunningly line-poor - except for atomic ions and molecular hydrogen emission; on the other hand, thanks to the high inclination of B, we confidently detect ice absorption bands of water, CO2, and NH4+. The H2 emission coming from the secondary traces a disc wind originating from the upper layer of the disc around HK Tau B, with a magnetohydrodynamic or photoevaporative origin; around HK Tau A, instead, the emission is much less extended. The detection and intensity of ionised lines is also different in the two sources. The stark contrast in the spectra, despite the potential common stellar origin, is likely to be attributed to physical mechanisms beyond the disc inclination.

Nienke van der Marel

The role of dust traps and dust transport in the disk composition

The transport of dust pebbles in protoplanetary disks is evident from ALMA observations over the last decade. In addition, there is increasing evidence both from observational as theoretical side that icy pebbles get transported inwards in the disk through radial drift, changing the local composition. Dust traps play a key role as they halt these inward drifting pebbles at various locations, either inside or outside various snow surfaces, allowing the ices to sublimate if inside the snow surface. Also vertical transport plays an important role here. Of particular interest are oxygen-containing molecules such as H2O and CH3OH, as they lower the local C/O ratio. Whereas sublimated CH3OH can be detected with ALMA, JWST/MIRI spectra offer a view on sublimated H2O. In this talk I will summarise the observational findings of sublimated CH3OH and H2O in disks with dust traps, and their implications for vertical dust transport.

Hubert Klahr

Formation of planetesimals in protoplanetary discs

Planetesimals are 10-100 km-sized bodies in the early Solar System and are defined as the smallest objects that are gravitationally bound and accrete via their own gravity. They represent a crucial intermediate step in planet formation theory, bridging the gap between dust grains and planetary embryos. While most of this hypothetically once vast population ultimately ended up in planets, at least in the Solar System we can still identify remnants in the form of minor bodies, ranging from asteroids and Kuiper Belt Objects to comets.

I will review the classical models of planetesimal formation, in particular the gravitational collapse of cm-sized pebbles as proposed by Safronov, Goldreich, and Ward, discuss the conjectures put forward by Weidenschilling, and describe their modern revival in combination with turbulent clustering and particle-driven turbulence, such as the streaming instability. In the Solar System, these models can be explored by confronting them with the observed size distribution of, for example, asteroids. However, many fundamental input parameters remain poorly constrained, including the size and size distribution of pebbles and the level of background turbulence. As a result, planet formation models often rely on favourable but simplified assumptions, which cannot yet be directly tested by observations of protoplanetary discs around young stars at sufficient precision. I will conclude with a courageous extrapolation of what we have learned from the Solar System to stars of different masses and metallicities.

Bibiana Prinoth

Right Time, Right Place: Probing Atmospheric C/O in Eccentric Warm Giants with VLT/CRIRES+

Transmission spectroscopy has become a cornerstone for characterising the atmospheres of close-in gas giants, providing constraints on their chemical composition, dynamics, and thermal structure. In the infrared, high-resolution spectrographs such as VLT/CRIRES+ have opened access to key molecular species including CO and H_2O, extending atmospheric studies beyond the hottest exoplanets.

As the field moves toward the ELT era, attention will increasingly shift to cooler and longer-period planets. For these targets, atmospheric signals are intrinsically weaker and more difficult to isolate, as smaller orbital velocities during transit limit the separation between planetary, stellar, and telluric spectral features. Eccentric warm giants offer a timely opportunity to already explore this regime: near periastron, their elevated orbital velocities temporarily enhance radial velocity separations, improving the detectability of atmospheric absorption despite otherwise challenging conditions.

I will present the results of a CRIRES+ survey, targeting H_2O and CO in four transiting, eccentric Saturn-mass planets, constraining their atmospheric C/O ratios. While C/O is not a unique diagnostic, it provides valuable context for interpreting giant planet formation pathways, migration histories, and disc chemistry when combined with other system properties. I will demonstrate that eccentric warm giants push current high-resolution infrared spectrographs close to their practical sensitivity limits for transmission spectroscopy. These observations establish a benchmark for future atmospheric characterisation with ELT/ANDES and underscore the importance of orbital architecture, timing, and strategic target selection in the next generation of exoplanet surveys.

Adrien Houge

A parameter study of leaky dust traps to quantify the radial transport of dust and volatiles in protoplanetary discs

To understand the properties of terrestrial planets and make sense of the chemical diversity measured with JWST, it is of great importance to model precisely the inward radial drift of icy pebbles, which transports large amounts of volatiles from the outer to the inner disc. Though this process is well understood in smooth protoplanetary discs, most observed discs tend to exhibit axis-symmetric gaps and dust traps, in which case the radial transport of pebbles is more complex. In this talk, I will discuss how we used the state-of-the-art dust evolution code DustPy to quantify the leakiness of dust traps created by a giant planet and map out the different leakiness regimes, thanks to an unprecedented parameter space exploration. I will then discuss the consequences of our findings for JWST observations, the NC/CC dichotomy in the Solar System, and pebble accretion beyond the pebble isolation mass.

Linn Eriksson

Planets and planetesimals at cosmic dawn

Low-mass, metal-enriched stars were likely present as early as cosmic dawn. I will present results from a study where I investigate whether these stars could have hosted planets and planetesimals in their protoplanetary disks. If so, these would have been the first planets to form in the Universe, emerging in systems with metallicities much lower than solar. Specifically, I explore whether vortices can facilitate the formation of planets and planetesimals in metal-poor disks.

Rafael Luque

Towards a holistic understanding of small exoplanets

Small exoplanets — super-Earths and sub-Neptunes — are the most common worlds in our Galaxy discovered to date, yet their origins, compositions, and potential habitability remain open questions. In this talk, I will review recent progress in understanding these planets from observations, from population-level trends to the detailed study of individual systems. Together, these results help build a more holistic view of small exoplanets and set the stage for the discoveries to come with JWST and future missions.

Anastasia Tzouvanou

Magnetic flux transport and structure formation in protoplanetary discs

Observations of protoplanetary disks have revealed the presence of substructures such as rings and gaps. Whether these features are signatures of embedded planets or result from purely disc-driven mechanisms remains an open question. Recent studies suggest that angular momentum transport in these discs is primarily driven by magnetised disc winds, rather than turbulence alone, highlighting the need to better understand large-scale magnetic field dynamics. In my work, I investigate the magnetic flux transport using global, axisymmetric, non-ideal magnetohydrodynamic (MHD) simulations to explore whether such structures could emerge from intrinsic disc processes. My models span a large radial range, from 5 up to 500 AU, and include Ohmic resistivity and ambipolar diffusion. By examining how fast magnetic flux is transported and in which direction, I aim to understand how magnetic field dynamics influence disc evolution and connect to the formation of large-scale disc features.

León-Alexander Hühn

Environmental Interactions of Protoplanetary Disks: Early-Stage Planetesimal Formation and Late Infall

Planets form in protoplanetary disks (PPDs) through a multi-scale process where micron-sized dust grows to pebbles and forms planetesimals. These planetesimals act as seeds to subsequent core and envelope accretion, eventually resulting in full-grown planets. From a theoretical standpoint, modeling of these processes is often performed under the assumption of an isolated disk. However, observational constraints on the dust-mass budget of PPDs, as well as the detection of substructures already in Class I disks, indicate that planet formation might start early during the Class 0/I stage. Here, the PPD is still embedded in its natal environment and subject to significant environmental interactions. I investigated whether planetesimals can already form at this stage, where turbulence is high but more material is available. Depending on the physical conditions, I find that 100 earth masses of planetesimals may form, which have a high water content. But environmental interactions are not limited to the early disk stages: Observations indicate ubiquitous inflow of material in the form of streamers onto PPDs in the Taurus and other star forming regions. Such interactions have considerable implications for planet formation during the Class II stage of PPDs, because they supply fresh material and impact disk dynamics. First, I investigated how such ”late infall” could be the reason for the planet-disk misalignment in IRAS 04125+2902, suggesting that the present-day disk may be the second generation. Furthermore, I considered which observational streamer signatures can arise under which environmental conditions, showing that turbulent Bondi-Hoyle-Lyttleton accretion processes can cause a variety of morphologies. Finally, I considered how these streamers can cause spiral structures, warps and accretion bursts of new material, highlighting the importance of including the effects of late infall in planet formation models.