Exoplanets & Planet Formation Workshop 2025

Book of Abstracts

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Format for each submission:
Family-Name, Given-Name(s) / Institute
Title
Abstract

Orals (in the sequence of the program):

Shigeru Ida / Institute of Science Tokyo
Title: Current understanding of gas giant planet formation and circumplanetary disks
Gas giants shape the architecture of planetary systems, and the RV observation data provide relatively less biased distribution of gas giants in exoplanetary systems. For example, the observed distribution of gas giants with masses $> 0.3\,M_{\rm J}$ shows a clear pile-up at the orbital periods $P > 300\,$days (the semimajor axes $> 1\,$au). The occurrence rate of these gas giants jumps up by a factor more than 3–5 there and it is almost constant as long as $P < 10^4$ days. The piled-up cold Jupiters would have higher masses than the hot and warm Jupiters. Recently, theoretical understanding of growth and migration of gas giants have been significantly progressed. Here I will summarize the recent developments in theory and discuss how the theory explains the gas giant pile-up beyond 1 au, interactions in growth and migration between multiple gas giants, and circumplanetary disks where moons may form.

Beibei Liu / ZJU
Title: modeling planet formation and the dependence on stellar host properties
The formation and evolution of planetary systems are linked to their host stellar environment. In this study, we employ a pebble-accretion-based planet population synthesis model to explore the correlation between planetary properties and stellar mass/metallicity. Our numerical results reproduce several main aspects of exoplanetary observations. First, we find that the occurrence rate of super-Earths, SE, follows an inverted V-shape in relation to stellar mass: it increases with stellar mass among lower-mass dwarfs, peaks at early M dwarfs, and declines toward higher-mass GK stars. Second, super-Earths grow ubiquitously around stars with various metallicities, exhibiting a flat or weak SE dependence on Za. Third, giant planets in contrast form more frequently around stars with higher mass/metallicity. Lastly, we extend a subset of simulations to 1 Gyr to investigate the long-term evolution of the systems' architecture. By converting our simulated systems into synthetic observations, we find that the eccentricities and inclinations of single-transit systems increase with stellar metallicity, while these dependencies in multi-planet systems remains relatively weak. The alignment between our results and observations provides key insights into the connection between planet populations and stellar properties.

Jinfei Yu / The University of Tokyo

Title: Icy Pebble Accretion and the Formation of Primordial Main Belt Asteroids

Main belt asteroids exhibit a radial compositional gradient, ranging from anhydrous bodies in the inner regions to increasingly volatile-rich compositions (including hydrated minerals, water ice, and even ammonium-bearing minerals) in the outer belt [1–3]. This gradient is particularly evident among the largest asteroids (D $\gtrsim$ 120 km), which are considered primordial remnants whose present-day properties likely preserve early Solar System conditions [4]. While a widely discussed hypothesis suggests that these volatile-rich asteroids formed in the outer Solar System and were later implanted into the main belt after disk dispersal [5,6], an alternative scenario invokes in-situ accretion of icy pebbles that drifted inward from the outer disk [7,8]. This icy pebble accretion scenario has not yet been quantitatively tested in detail, and recent advances in observations now provide constraints to test these models [2,9]. Here we quantitatively investigate the delivery of H_2O, NH_3 and CO2 to large main belt asteroids via icy pebble accretion during the inward migration of these snowlines. We adopt a simplified protoplanetary disk model with prescribed snowline evolution[10], and treat turbulence strength, pebble flux, and pebble size (expressed via the Stokes number, St) as free parameters. Using semi-analytical formulas for pebble accretion[11,12], we compute the accretion efficiency and evaluate the results against observational constraints on volatile abundance and inferred layer thicknesses. We find that to reproduce the present-day mass, ∼30 wt% water content, ammonium-bearing icy layer of the largest asteroid (dwarf planet) Ceres from a rocky embryo requires a moderate pebble flux (<20 M⊕). Under this constraint, matching the volatile content of other large main belt asteroids (D $\geqslant$ 120 km) requires accretion of small pebbles (St $\lesssim 10^{-3}$, or $\lesssim$1,mm) for water, and even finer particles (St $\sim 10^{-5}$, or ∼10,µm) for ammonia. However, such small pebbles are challenging to sustain due to high local dust-to-gas ratios ($\gtrsim$1), and are inconsistent with the observed size distributions in protoplanetary disks [13]. If St $\gtrsim 10^{-3}$, the resulting volatile layer is typically thinner than 1,km—insufficient to globally coat asteroids, many of which are 100–200,km in size with ammoniated signatures [2,6,9]. These findings suggest that the in-situ icy pebble accretion scenario faces considerable challenges in reproducing the volatile enrichment observed in large main belt asteroids.

Kangrou Guo / TDLI

Title: Formation of Free-Floating Planets via Ejection: Population Synthesis with a Realistic IMF and Comparison to Microlensing Observations

Microlensing observations suggest that the mass distribution of free-floating planets (FFPs) follows a declining power-law with increasing mass. Assuming FFPs originate from planet–planet scattering and ejection, we model their mass function using a planet population synthesis framework for single-star systems combined with N-body simulations. Our models adopt a realistic stellar initial mass function (IMF, Koshimoto et al. 2021), which naturally results in a large fraction of planetary systems orbiting low-mass stars (M dwarfs). We find that the predicted FFP mass function agrees well with microlensing results (Sumi et al. 2023), especially when this IMF is taken into account. In this scenario, giant planets—though rare around M dwarfs—play a key role when present by triggering dynamical instabilities that eject smaller companions. In systems without giants, planets of a few Earth masses located beyond $\simeq$ 10,au dominate the progenitor population of FFPs. This pattern is particularly common around M dwarfs, whose shallow gravitational potential in the outer disk makes ejection by mutual scattering more efficient. We also compare the mass distribution of bound planets with microlensing observations and find a dip in planet occurrence around a log mass ratio (planet-to-host mass) of -3.5 to -3, consistent with recent survey results. However, our model tends to overestimate the frequency of super-giant planets (masses $\gtrsim 1000$ Earth masses or log mass ratio > -2.5), which may reflect uncertainties in gas accretion physics or observational challenges in distinguishing massive FFPs from stellar objects. Upcoming missions such as the Roman Space Telescope will improve constraints on both the bound and unbound planet populations, offering critical tests of formation and ejection models.

Yuya Fukuhara / ASIAA

Title: Hydrodynamical simulations of the vertical shear instability with dynamic dust and cooling rates in protoplanetary disks

Turbulence in protoplanetary disks affects dust evolution and planetesimal formation. The vertical shear instability (VSI) is one of the candidate turbulence-driving mechanisms in the outer disk region. Since the VSI requires rapid gas cooling, dust particles in disks can influence and potentially control VSI-driven turbulence. However, VSI-driven turbulence has strong vertical motion, causing vertical diffusion of particles. As a result of this interaction, it remains unclear how turbulent structures and dust distributions form and persist. To investigate how the VSI drives turbulence and maintains a balance between dust settling and diffusion, we perform global two-dimensional hydrodynamical simulations of an axisymmetric protoplanetary disk. These simulations account for the dynamic interplay between dust distribution, cooling rates, and turbulence. We find that VSI mixing, dust settling, and local dust cooling reach an equilibrium, forming a thick dust layer with a dimensionless vertical mixing coefficient of approximately 10^{-3}. The ability of the VSI to sustain this state also depends on the dust size and dust-to-gas mass ratio. Larger grains or lower mass ratios weaken turbulence, leading to dust settling. The condition of equilibrium state existence is consistent with the prediction of the semi-analytic model presented by Fukuhara & Okuzumi (2024). Our results indicate that turbulence in VSI-dominated disks has different levels of intensity depending on the grain size. This suggests that the efficiency of dust growth can depend on the VSI in protoplanetary disks.

Shiang-Chih Wang / ASIAA

Title: Azimuthal-drift streaming instabilities in accreting protoplanetary disks

The streaming instability (SI) is one of the key mechanisms for forming km-sized planetesimals from dust grains or pebbles, which is a critical step in the standard core accretion scenario of planet formation. In the presence of a radial pressure gradient, SI can locally enhance the dust-to-gas ratio to the point of gravitational collapse, overcoming both the collisional and radial drift barriers to grain growth. Recent studies have identified a new form of SI, driven by the azimuthal velocity difference between dust and gas. This velocity difference arises from gas accretion due to magnetic torques and is termed the azimuthal-drift streaming instability (AdSI). Unlike classical SI, AdSI remains effective even in the absence of a radial pressure gradient. In our work, we extend previous studies of both AdSI and classical SI by performing a large parameter survey using axisymmetric shearing box simulations. With dust initially settled at the midplane, we find that AdSI generates vertically extended dust filaments even at low initial dust-to-gas ratios ($\epsilon = 0.01$), and maximum dust-to-gas ratios of

$\sim$100 are achieved for $\epsilon > 1$, sufficient to trigger gravitational collapse. Notably, we also observe that accretion flows can drive filament formation even in systems where classical SI dominates. To explore how filament structures behave in stratified disks, we include vertical gravity in our models. Our study sheds light on the role of AdSI in inducing strong dust clumping and its potential to trigger classical SI, thereby facilitating planetesimal formation.

Qiang Hou / SYSU

Title: Streaming Torque in Dust-Gas Coupled Protoplanetary Disks

In this talk, I will present our recent studies on the streaming torque—a novel torque component arising from dust–gas coupling in the presence of radial pressure gradients in protoplanetary disks. Unlike classical type I torques, which originate purely from gas dynamics, the streaming torque is driven by the inward drift of dust relative to gas, which generates a leading dust wake ahead of embedded planets and induces a net torque. Depending on the specific disk properties, this torque can slow down, halt, or even reverse planetary migration, providing a potential mechanism to retain planetary cores in their formation regions. In particular, when the dust stopping time exceeds $\sim$0.1 (in units of the local orbital time), outward migration can occur due to the enhanced asymmetry in the dust distribution. These results highlight the crucial role of dust–gas coupling in planet–disk interactions and suggest that dust dynamics must be incorporated into models of planet formation and migration.

Jiaqing Bi / MPIA

Title: Shoulder of Dust Rings Formed by Planet-disk Interactions

Recent analyses of mm-wavelength protoplanetary disk observations have revealed several emission excesses on the previously identified dust rings, referred to as the shoulders. The prevalence of the shoulders suggests that they trace a common but unclear mechanism. In this work, we combine 3D, multifluid hydrodynamic simulations with radiative transfer calculations to provide explanations for the formation of the shoulders. We find that the ring–shoulder pairs can result from the 3D planet–disk interactions with massive, gap-opening planets. Possible mechanisms are the dust filtration effect by the outward gas flow at the outer gap edge, the warmed-up dust due to the puff-up, and the merger of puff-ups at both gap edges due to insufficient resolution. Our work bridges the correlation between the ongoing planet–disk interactions and the existence of an inner dust shoulder in the PDS,70 disk. It also provides insights into the formation of outer shoulders in other disks and highlights the role of 3D effects in planet–disk interaction studies.

Riouhei Nakatani / University of Milan

Title: Revisiting Protoplanetary Disk Dispersal

Protoplanetary disks are the birthplaces of the planets in our Solar System and $\sim$6000 exoplanets discovered to date. Composed of gas and dust, they provide the raw materials for planet formation. As planets take shape, the disks themselves dynamically evolve and eventually dissipate. This raises two fundamental questions: When do PPDs disperse, and what physical processes drive their dispersal? These lie at the heart of the so-called disk dispersal problem, a central challenge in planet formation theory. PPDs are currently thought to survive for a few million years, losing mass through accretion onto the host star and winds launched from their surfaces. Accretion is driven by angular momentum transport, facilitated by turbulence and/or magnetohydrodynamics (MHD) winds. Disk winds, in turn, are powered by MHD processes and/or photoevaporation. While our understanding of disk lifetimes and dispersal mechanisms has advanced significantly in recent decades, many questions remain. In particular, the discovery of long-lived disks around both M-dwarfs and intermediate-mass stars challenges the conventional picture and highlights the need to revisit existing models of disk dispersal. More recently, the James Webb Space Telescope (JWST) has opened new avenues for studying disk dispersal, offering new insights into the dispersal process. In this talk, I will discuss how our understanding of disk dispersal is evolving in light of these new discoveries and highlight prospects for future studies in this rapidly evolving field.

Shoji Mori / Tsinghua University

Title: Thermal Structure and Evolution of Magnetized Protoplanetary Disks: Implications for Planet Formation

Understanding the temperature structure and its evolution in protoplanetary disks is essential for developing a comprehensive theory of planet formation. The thermal profile governs the dust composition and phase transitions, which in turn affect the bulk composition of forming planets. In addition, both the growth and orbital migration of protoplanets are strongly regulated by the temperature structure of the disk. Accurate modeling of the thermal structure requires capturing the underlying disk dynamics, including disk accretion and energy transport processes. In this talk, I present our latest global magnetohydrodynamic (MHD) simulations that incorporate full non-ideal MHD effects and radiation transport. We show that accretion heating is generally inefficient across a wide range of disk magnetizations. I also discuss the long-term thermal evolution of magnetized disk models, based on MHD simulation results. Compared to viscously heated disks, MHD disk models more readily lead to the formation of both rocky super-Earths and volatile-rich sub-Neptunes, highlighting the crucial role of MHD disks in shaping planetary systems.

Haruhi Enomoto / Science Tokyo

Title: A local non-Ideal MHD framework consistent with global magnetic-field structures in protoplanetary disks

Large-scale vertical magnetic fields threading protoplanetary disks drive magnetocentrifugal winds. The stresses exerted by these winds also induce accretion flow on the disk surface, where the ionization fraction is relatively high. Reproducing this ”layered” accretion in local shearing-box simulations is difficult because the toroidal field generated by Keplerian shear rapidly accumulates and breaks the physical geometry of the magnetic field lines with a flip in the horizontal fields. In this study, we propose a new shearing-box model that mitigates the issue mentioned above. Our model adopts a flux-regulation step that removes horizontally averaged toroidal fields at every timestep, emulating the slow radial magnetic diffusion present in global disks. Our local stratified simulations with ohmic and ambipolar resistivities maintain a stable, antisymmetric toroidal-field geometry and persistent surface accretion layers for longer than 50 orbits. The vertical profiles of the mass flux, accretion velocity, and layer thickness agree with analytically self-similar solutions to within 10% accuracy, confirming that once toroidal-flux buildup is controlled, local simulations recover the correct global magnetic-field geometry and associated accretion dynamics. Because our new local model is computationally less expensive than global models, it enables systematic, high-resolution exploration of how the ionization chemistry and dust evolution control layered accretion driven by MHD winds.

Jing Yang / Tsinghua University

Title: Radiation hydrodynamic models of circumplanetary disks

Circumplanetary disks (CPDs) are important to moon formation and late-stage planet formation. However, they are extremely poorly understood due to the lack of observables and comprehensive theoretical models. To fill this gap, we present a 2D viscous axisymmetric radiation hydrodynamic model of CPDs. We adopt Shakura–Sunyaev α disk model for viscosity and flux-limited-diffusion approximation for radiation transport. The model is built with `Guangqi`, a new radiation hydrodynamic code that can work with complex equation of state, and precisely conserve angular momentum in the polar direction. We conduct a suite of nine simulations, systematically varying planet mass, viscous α, and the density profile of infalling gas, and seek their quasi-steady-state (QSS) configurations. The resulting accretion efficiency ranges from 30% to 80%, decreasing with increasing angular momentum of the infalling material. We find that silicate dust may be sublimated inside the CPDs when α is small or the mass feeding rate is high. We also find that, as the planet mass increases, the disk aspect ratio decreases, and the circumplanetary material transits from circumplanetary envelope to circumplanetary disk. To further probe angular momentum transport in non-magnetized CPDs, we perform an inviscid simulation. In this case, accretion efficiency drops to only 4.2%, with most of the gas locked in convective eddies. The effective α associated with Reynolds stress is found to be $\lesssim 10^{-6}$, highlighting the inefficiency of angular momentum transport in the absence of explicit viscosity.

Jianheng Guo/ YNAO

Title: Hydrodynamic escape of hydrogen-rich atmosphere in close-in exoplanets

TBD

Helong Huang / Tsinghua University

Title: How turbulent diffusivity changes the exoplanet clouds composition: a sweet spot Kzz for silicate feature

Turbulence is very important in shaping the location and extent of clouds in exoplanet atmospheres, because it dredges up the vapor material and transports clouds upward in the atmosphere. We incorporate a self-consistent cloud formation model including diffusion with a simplified two-stream radiative transfer method. Using an iterative method, the temperature-pressure profile and cloud structure reach an equilibrium state. When an atmosphere is characterized by strong vertical turbulence, clouds diffuse to the upper atmosphere and become more extended in thickness. This effect significantly lifts the photosphere in the visual band, absorbs stellar photons and increases the temperature, even causing a temperature inversion. As a result, silicates in the upper atmosphere evaporate and the clouds become dominated by more refractory material (e.g., Fe). Therefore, turbulent diffusivity not only affects the cloud thickness but also the cloud composition. Consequently, the transmission spectrum of a strongly turbulent cloudy planet shows no silicate features but strong extinction of molecular lines, and the emission spectrum shows emission features of water and clouds. There exists a sweet spot K_{zz} where silicate features can appear in the transmission spectrum. With the radiative feedback of clouds taken into consideration, turbulence strongly affects the cloud composition and can be constrained from transmission or emission spectra by telescopes like JWST.

Wei Zhong / NJU

Title: Irradiated Atmosphere V: Effects of Vertical-Mixing induced Energy Transport on the Inhomogeneity

Atmospheric variations over time and space boost planetary cooling, as outgoing internal flux responds to stellar radiation and opacity. Vertical mixing regulates this cooling. Our study examines how gravity waves or large-scale induced mixing interact with radiation transfer, affecting temperature inhomogeneity and internal flux. Through the radiative-convective-mixing equilibrium, mixing increases temperature inhomogeneity in the middle and lower atmosphere, redistributing internal flux. Stronger stellar radiation and mixing significantly reduce outgoing flux, slowing cooling. With constant infrared (IR) opacity, lower visible opacity and stronger mixing significantly reduce outgoing flux. Jensen's inequality implies that increased stellar flux and opacity contrasts raise the mean internal flux ratio ($\bar{F}_{\rm int}/F_{\rm int,homo}$), where $\bar{F}_{\rm int}$ is the average internal flux of two inhomogeneous columns and $F_{\rm int,homo}$ is that of a corresponding homogeneous column. This effect, especially under strong opacity contrast, enhances deep-layer temperature inhomogeneity and can potentially boost cooling. However, in the mixing case, overall cooling is suppressed relative to the non-mixing scenario, as both $\bar{F}_{\rm int}$ and $F_{\rm int,homo}$ decrease—more significantly for the latter. Thus, while vertical mixing-induced inhomogeneity can enhance cooling, the overall cooling effect remains weaker than in the non-mixing case. Therefore, vertical mixing, by regulating atmospheric structure and flux, is key to understanding planetary cooling.

——————— Lin-bridge Undergraduate Forum ———————

Yi Huang / ZJU

Title: Study on the origin of water on Earth and its distribution across Earth's spheres in the process of planetary formation

Water (H_2O), a compound of hydrogen and oxygen—two of the most abundant elements in the universe—is ubiquitous in cosmic environments. Among terrestrial planets in our solar system, Earth is unique for its extensive surface water reservoirs, which played a pivotal role in life's origin and evolution. To investigate Earth's water provenance and its geospheric distribution during planetary formation, we employ numerical simulations of terrestrial accretion. We examine contributions from two potential sources: carbonaceous chondrites (CC) and primordial nebular gas. Key model parameters include: (1) water/hydrogen abundances from both sources, (2) hydrogen isotopic composition

(D/H) of carbonaceous chondrites, (3) preferential incorporation of hydrogen isotopes into the iron-rich core, (4) timing of water delivery during accretion, and (5) intensity of planetary embryo collisions. The model is validated against mantle-observed water concentrations and hydrogen isotopic ratios. Results indicate nebular gas-derived hydrogen shows greater sensitivity to variations in Earth's formation stages. Further constraints from geochemical analyses and planetary formation studies are needed to advance understanding of Earth's aqueous evolution.

Haolin Li / Beijing Normal University

Title: Detecting Lava Oceans on Hot Exoplanets Using the Glint Effect

Theory and models predict that extremely hot rocky exoplanets ($T > 850$ K) could be covered with lava oceans. However, direct observational evidence of lava oceans remains elusive. Here we show that phase curves can distinguish between planets with: (1) smooth, molten surfaces (lava-ocean) versus (2) rough, solid surfaces (Moon- or Mercury-like).

We demonstrate that lava oceans should be sufficiently smooth to exhibit specular reflection, producing an ocean "glint" effect. Using both numerical and analytical models, we solve for the reflected/emitted light from surfaces with specular versus Lambertian reflection. Key findings include:

The phase curve of a specular surface is significantly flatter than the sinusoidal Lambertian case

The phase curve amplitude becomes notably smaller than the secondary eclipse depth

Incorporating Fresnel's law predicts twin peaks near transit for low-albedo surfaces

Our analysis reveals that phase-curve variations from the glint effect can identify smooth molten surfaces. This method shows particular promise for characterizing hot rocky exoplanets with thin atmospheres using JWST observations.

Ruiqi Yang / SYSU

Title: Misaligned circumbinary discs around unequal-mass eccentric binaries: alignment, morphology, and binary accretion variability

Binary systems are ubiquitous in the Universe and can host circumbinary discs in gaseous environments, which are often observed to be misaligned with the binary orbital plane. Such misalignments can significantly influence disc evolution, accretion dynamics, and binary evolution. We conduct hydrodynamical simulations to model the circumbinary discs with initial tilts from 0° to 180° in 15° intervals, around eccentric binaries with mass ratios $q_\mathrm{b} = M_2/M_1 \in \{0.67, 0.43, 0.25, 0.11\}$. We recover three known disc alignments: coplanar prograde, polar, and coplanar retrograde. The alignment timescale increases as q_b decreases. Consistent with previous works, polar discs form more compact cavities than coplanar discs, and retrograde discs maintain smaller cavities than prograde discs across varying q_b. Accretion variability depends strongly on disc alignment and binary mass ratio. Coplanar prograde discs show preferential alternating accretion due to the cavity edge precession. Polar discs favour accretion onto the primary, whereas retrograde discs favour the secondary for large accretion radii, shifting to the primary for smaller radii, especially at small q_b. When disc breaking occurs, the inner disc becomes eccentric and causes alternating accretion before aligning polar. As it circularises, the accretion shifts back to a non-alternating pattern. Disc mass loss through accretion depends on the initial tilt. Polar discs retain most of their initial mass, while warped and broken discs are accreted more quickly. With the same initial tilt, both prograde discs that do not break and polar discs exhibit increasing mass loss as $q_{\rm b}$ decreases. Our findings provide insights into observed circumbinary disc systems and have implications for circumbinary planet formation.

Yangjun Pu / NJU

Title: Massive Retrograde Moons May Survive During Different Hot Jupiters' Migration Scenario

Hot Jupiters are giant planets with orbital period of less than 10 days. They typically move to their present orbits via disk migration and high-eccentricity migration mechanisms. Because they are too close to their stars, it is generally believed that they cannot have satellites. We enlarge the reduced Hill sphere boundary range of hot Jupiters through the Rebound program, and perform a dynamic simulation of the formation of hot Jupiters after taking into account factors such as hot Jupiter reinflation and satellite tidal forces. We find that retrograde moons could maintain stable after disc migration. Secondly, massive retrograde moons (larger than 10 Earth mass) might survive (3%) during process of coplanar excitation and become moons orbiting hot jupiters or free-floating planets. Our results may help to identify samples of hot Jupiters which have potential to retain moons.

Bohang Zhu / NJU

Title: Simulation and Modeling of Interferometric Imaging for Binary Systems

Optical interferometric imaging has shown great promise in the field detection of exoplanets. The proposed Meayin mission aims to explore potentially habitable terrestrial planets in the solar neighborhood by utilizing high-contrast mid-infrared nulling interferometry. To assess the capabilities of such interferometric techniques in detecting binary and star-planet systems, we conduct a series of simulated observations. In this study, we adopt both two-telescope and four-telescope X-array configurations, systematically varying the baseline lengths and angles to simulate the interferometric response of representative binary systems in the universe, including stellar binaries and star-planet systems. The target models include both point sources (e.g., stars, planets) and extended sources (e.g., semi-detached binaries). To more realistically reflect observational conditions, we incorporate typical error sources such as Poisson noise and pointing accuracy errors into the simulations. During data analysis, we perform parameter inversion based on the simulated interferometric signals. For point-source targets, we recover basic physical parameters such as angular separation and relative flux. For extended sources, we reconstruct the morphological structures and surface brightness distributions. Under the assumption of high nulling contrast, our results demonstrate that this technique is not only effective for conventional target characterization, but also holds potential for detecting subtle features such as exomoons and planetary rotation signals. Furthermore, the simulation framework developed in this work serves as a tool for future space-based interferometric missions. It enables the pre-selection of optimal targets and the formulation of observation strategies, providing theoretical support for both instrument development and scientific planning.

Zhiqi Zhang / ZJU

Title: Probing Magnetic Fields in Protoplanetary Disks through Polarized Scattering by Magnatically Aligned Dust Grains

Magnetic fields play a crucial role in the evolution of protoplanetary disks, particularly in the disk atmosphere where magnetically driven disk winds are launched. In recent years, near-infrared polarimetric observations (e.g., with VLT/SPHERE) have provided a novel approach to probing disk magnetic fields. Magnetically aligned grains can induce polarization orientations that significantly deviate from the traditional azimuthal pattern, and under certain conditions, even exhibit a "polarization reversal" along the radial direction. The key difference between magnetically aligned grains and non-aligned dust grains lies in the significant U_{phi} signals. In this work, we investigate how different magnetic field configurations influence polarization patterns in protoplanetary disks, focusing on quantifying the structures in the U_{phi} maps and their dependence on the magnetic field configurations. I hope this work will pave the way to using near-IR polarimetry to probe magnetic fields in protoplanetary disks, providing key insights into the physical processes during the early stages of planet formation.

Xiang Ji / Tsinghua University

Title: The interior structure of gas-water worlds

Two hypotheses are commonly invoked to explain why sub-Neptunes exhibit larger radii than super-Earths: the "gas dwarf" and "water world" scenarios. The Kepler mission has identified planets with even lower bulk density, whose evolution histories remain a mystery. Here we integrate the two hypotheses to present a novel planet evolution model for these super-puffy planets. We propose a planet structure of Hydrogen-Helium envelop surrounding a layered core, primarily composed of water, and employ a smooth transition in outer boundary conditions to simulate the process of protoplanetary disk dispersal. We demonstrate that this model aligns well with observation data of certain planets, particularly Kepler-51c. Our findings provide a solid foundation for constraining the internal composition and structure of super-puffy planets.

—————————— Lin-bridge Undergraduate Forum ——————————

Di-Chang Chen / SYSU

Title: Hot Jupiter Origin and Tidal Evolution Constrained by the Age–Frequency Relation

The discovery of hot Jupiters has challenged classical planet formation theory. While multiple formation mechanisms have been proposed, their relative contributions remain unclear. Hot Jupiters also provide a unique testbed for tidal theory, particularly the tidal quality factor (Q') which remains poorly constrained. Using a sample of hot Jupiters orbiting Sun-like stars with kinematic data, we find: (1) a broken age-frequency relation with a distinct ridge at $\sim$2 Gyr, and (2) evidence for multi-origin formation with different timescales. Our analysis yields two key constraints: First, the tidal quality factor for Sun-like stars is $\log Q' \approx 5.7$, consistent with observed orbital decay rates. Second, we quantify formation channels showing $\sim$70% form rapidly (< 0.5 Gyr) via in-situ formation, disk migration, planet-planet scattering, or Kozai-Lidov cycles, while $\sim$30% form later ($\sim$1-5 Gyr) via secular chaos. The obliquity distribution of late-arrival hot Jupiters further supports this dichotomy. These results provide the first unified framework reconciling hot Jupiter demographics with multi-channel formation.

Bo Ma / SYSU

Title: Measuring Exoplanet Orbital Decay using TTV

I will report some of our group's recent works, in which we tried to measure the orbital decay of exoplanets in short orbital period. We have utilized TESS, HST and JWST data and identified several candidates showing signs of orbital decay.

Huigen Liu / SYSU

Title: Photo-dynamical Analysis of TOI-1338: A Fully Coplanar Configuration with a Puffy Planet

TOI-1338 is the first circumbinary planet (CBP) system discovered by TESS. It has one transiting planet at $P \approx 95$ days and an outer nontransiting planet at $P \approx 215$ days complemented by radial velocity (RV) observation. Here we present a global photodynamical modeling of the TOI-1338 system that self-consistently accounts for the mutual gravitational interactions between all known bodies in the system. As a result, the three-dimensional architecture of the system can be established by comparing the model with additional data from TESS Extended Mission and published HARPS/ESPRESSO RV data. We report an inconsistency of binary RV signal between HARPS and ESPRESSO, which could be due to the contamination of the secondary star. According to stability analysis, the RV data via ESPRESSO are preferred. Our results are summarized as follows: (1) The inner transiting planet is extremely coplanar to the binary plane ($i \approx 0.12°$), making it a permanently transiting circumbinary planet at any nodal precession phases; we updated the future transit ephemerides with improved precisions. (2) The outer planet, despite its untransiting nature, is also coplanar with the binary plane ($< 22°$ for the 99% upper limit). (3) The inner planet could have an extremely low density of 0.137 ± 0.026 g cm^{-3}. With a TESS magnitude of 11.45, TOI-1338 b is an optimal circumbinary planet CBP for ground-based follow-up and transit spectroscopy.

Peiwei Tu / NJU

Title: PAST. VI. Age Dependence of the Occurrence and Architecture of Ultra-Short-Period Planet Systems

Ultra-short-period (USP) planets, with orbital periods shorter than one day, represent a unique class of exoplanets whose origin remains puzzling. Determining their age distribution and temporal evolution is vital for uncovering their formation and evolutionary pathways. Using a sample of over a thousand short-period planets around Sun-like stars and kinematic methods from the Planets Across Space and Time (PAST) project, we find that the host stars of USP planets are relatively older than other short planets. Subsequently, we find that the occurrence of USP planets increases with time. Furthermore, we uncover evidence indicating that USP planetary system architectures evolve on Gyr timescales, as evidenced by the period distribution, orbital spacing, and transiting planet multiplicity. Our findings suggest most USP planets originated via inward migration driven by tidal dissipation over Gyr timescales. This work reveals the age-dependence of USP planet systems' occurrence and architecture, providing new constraints for future studies to further distinguish between different formation mechanisms of USP planets.

Akimasa Kataoka / NAOJ
Title: Dust properties and planet formation revealed by ALMA observations
Dust coagulation is the first step of planet formation and can be directly tested through observations of protoplanetary disks. Thanks to ALMA's high resolution and sensitivity, disk structures and their multi-wavelength and polarization signatures have become accessible. In this talk, I review recent methodological advances for constraining dust properties such as millimeter-wave polarization and multi-wavelength continuum analysis and summarize what these constraints reveal about grain sizes, porosities, and the early stages of planet formation.

Thiem Hoang / KASI
Title: Alignment, Dust Polarization, and Dust Evolution in Protoplanetary Disks and Planetary Systems
Magnetic fields are believed to play a crucial role in the formation and evolution of protoplanetary disks. Dust polarization from aligned grains is one of the most powerful techniques for probing magnetic fields; however, whether grains can be aligned with magnetic fields in dense environments remains an open question. In this talk, I will first present the latest grain alignment theory based on radiative torques (RATs) and magnetic relaxation (MRAT), along with synthetic polarization observations obtained with our new `POLARIS` code. By comparing the synthetic dust polarization with ALMA observations, we demonstrate that grain alignment remains efficient even in dense protostellar environments ($n_{\rm H} \gtrsim 10^6$ cm^{-3}), owing to grain growth and strong protostellar radiation. As a result, dust polarization can reliably trace magnetic fields beyond $\sim$100 au in protoplanetary disks. I will then explore how grain alignment influences grain growth in dense environments, proposing that alignment with magnetic fields not only promotes grain size growth but also enhances grain elongation. Next, I will discuss our recent findings on grain alignment and rotational disruption induced by RATs in planetary systems, highlighting how RAT trapping significantly suppresses both alignment and disruption. Finally, I will introduce Korea's L4 space mission, which will carry a dust detector designed to measure dust properties and uncover the formation history and evolution of our Solar System.

Thiem Hoang / KASI
Title: Alignment, Dust Polarization, and Dust Evolution in Protoplanetary Disks and Planetary Systems
Magnetic fields are believed to play a crucial role in the formation and evolution of protoplanetary disks. Dust polarization from aligned grains is one of the most powerful techniques for probing magnetic fields; however, whether grains can be aligned with magnetic fields in dense environments remains an open question. In this talk, I will first present the latest grain alignment theory based on radiative torques (RATs) and magnetic relaxation (MRAT), along with synthetic polarization observations obtained with our new `POLARIS` code. By comparing the synthetic dust polarization with ALMA observations, we

demonstrate that grain alignment remains efficient even in dense protostellar environments ($n_{\rm H} \gtrsim 10^6$ cm^{-3}), owing to grain growth and strong protostellar radiation. As a result, dust polarization can reliably trace magnetic fields beyond $\sim$100 au in protoplanetary disks. I will then explore how grain alignment influences grain growth in dense environments, proposing that alignment with magnetic fields not only promotes grain size growth but also enhances grain elongation. Next, I will discuss our recent findings on grain alignment and rotational disruption induced by RATs in planetary systems, highlighting how RAT trapping significantly suppresses both alignment and disruption. Finally, I will introduce Korea's L4 space mission, which will carry a dust detector designed to measure dust properties and uncover the formation history and evolution of our Solar System.

Yangfan Shi / PKU

Title: Constraining Dust Property and Test Dust Trapping in the Outer Ring of MWC 480 by ALMA and VLA Observations

Concentric rings and gaps in protoplanetary disks have been frequently seen in high resolution observations at millimeter wavelength by the Atacama Large Millimeter/submillimeter Array (ALMA). These features are thought to be generally associated with gas pressure bumps that trap mm-sized grains. Larger grains should also be trapped at the pressure maxima, while centimeter emission of these substructures is not always consistently detected as those at shorter wavelength. In this work we present new observations of the disk around MWC 480 using the Karl G. Jansky Very Large Array (VLA), with an angular resolution of $\sim$0.1$''$ and a very deep sensitivity of $\sim$1 μJy/beam at Ka Band (9 mm). The source hosts a central blob and an outer ring at $\sim$100 au at millimeter wavelength. We detect an outer ring substructure at 9 mm, consistent with the ring present at shorter millimeter wavelength. By combining with the ALMA observations, we characterize the difference of the ring morphology at different wavelengths and measure the spectral index of the ring. We fit the spectral energy distribution (ALMA Band 7, 6, and 3, and VLA Ka Band) at different radius with a physical model (including dust scattering) to constrain the dust growth and dust trapping in the ring.

Tomohiro Yoshida / NAOJ

Title: Revealing Gas Surface Density Profiles in Protoplanetary Disks via Pressure-Broadened CO Line Wings

Observational constraints on the gas surface density in protoplanetary disks are essential for understanding planet formation. However, direct measurements have been extremely challenging due to the lack of a reliable tracer of the main component of the gas, hydrogen, leading to uncertainties spanning orders of magnitude. To address this, we have developed a novel method that utilizes the pressure broadening of CO emission lines, which is an effect that has long been overlooked. Since pressure-broadened CO lines are sensitive to the hydrogen volume density, this approach enables direct determination of the total gas surface density. We report the first detection of pressure-broadened CO line wings in three protoplanetary disks. By analyzing the line wings, we successfully derive their gas surface density profiles using a tracer directly sensitive to hydrogen gas for the first time. The estimated gas surface densities exceed that of the minimum-mass solar nebula, suggesting that the conditions necessary for planet formation are quantitatively satisfied.

Xianyu Tan / SJTU

Title: Modeling the atmospheric circulation and spectra of cloudy hot Jupiters

Clouds play a significant role in shaping planetary atmospheres. Observationally, clouds tend to mute spectral features, obscuring our inference of fundamental parameters of planetary atmospheres such as abundances and structure measurements. On the other hand, clouds in hot Jupiters' atmospheres, due to their strong radiative effects in high-temperature atmospheres and their coupling with atmospheric flows, facilitate a new window to probe climate dynamics in a regime that has never been encountered in our solar system planets. For both reasons, understanding clouds in a self-consistent dynamical framework is vital. This presentation will update our latest findings of cloud dynamics and their consequences on atmospheric heat transport and observational signatures of the spectrum based on general circulation models of hot Jupiters.

Wenzhan Ouyang / SJTU

Title: Constraining the early atmospheric evolution of the TRAPPIST-1 system through dynamical signatures

The TRAPPIST-1 system hosts seven planets locked in complex mean motion resonances (MMRs), indicative of a stable yet intricate dynamical history. These planets likely possessed primordial hydrogen-dominated atmospheres that underwent significant photoevaporation-driven mass loss early on. This atmospheric escape may have critically shaped their current orbits and system stability. We aim to investigate the long-term evolution of the TRAPPIST-1 system with atmospheric mass loss. By exploring the impact of this atmospheric mass loss on orbital configurations, we aim to constrain the planets' initial atmospheric conditions. We employ N-body simulations to model the long-term evolution of the TRAPPIST-1 system, incorporating mass loss and orbital changes due to angular momentum transfer between escaped gas and the planet. These simulations allow us to track changes in the planets' orbits under different mass loss scenarios, testing various mass loss fractions and angular momentum transfer efficiencies. Our simulations demonstrate that even modest atmospheric loss ($\sim$1.8% mass loss for TRAPPIST-1 b, assuming angular momentum conservation) induces significant orbital reconfiguration. Mass loss drives orbital expansion of the innermost planet, triggering convergent migration. This leads to increased planetary eccentricities and a measurable shift in the 3-body resonant angle of the b-c-d triplet, indicating substantial disruption to the resonant architecture. This demonstrates that a mass loss fraction of around 2% can lead to noticeable changes in the system's orbital configuration. We conclude that the TRAPPIST-1 planets likely retained no more than 6% of their primordial atmospheres during formation, providing new constraints on the system's early atmospheric evolution.

Junda Zhou / YNAO

Title: Estimating Stellar Age Based on Planetary Water Content Inversion: The Case of GJ 486b

The evolution of planetary atmospheres and water content not only influences habitability but also provides clues for inferring the age of their host stars. In this study, we develop a method to estimate the age of the M dwarf GJ,486 by integrating water content inversion with a planetary formation dataset. We treated the stellar age as a free parameter and inverted the current water content within the parameter space of initial water content and hydrogen-rich atmospheric mass. We then proposed a probabilistic framework, incorporating the planetary formation dataset, to evaluate the likelihood of various stellar ages. After smoothing with a Gaussian kernel density estimator, we derived a continuous probability distribution. The most probable stellar age was found to be $2.47^{+6.43}_{-2.47}$,Gyr (3σ range: 0–8.9,Gyr), which closely matches but is independent of previous estimates. With further observations set to enhance exoplanet water content measurements, our approach holds significant potential for inferring age and advancing the study of planetary habitability across similar systems.

Tamami Okamoto / TDLI

Title: Jovian atmosphere's noble gas enrichment via disk photoevaporation

The data from the Galileo probe's direct measurements showed that the abundances of noble gases such as argon, krypton, and xenon in the Jovian atmosphere are approximately three times higher than solar levels. This enrichment has puzzled scientists, given the wide range of condensation temperatures for noble gases. Guillot & Hueso (2006) proposed a model involving disk photoevaporation in the outer disk region, where noble gases could condense on dust surfaces. They suggested that the removal of the noble-gas-depleted disk gas through photoevaporation would suppress its accretion onto the Jovian core and result in relatively higher abundances of noble gas species. However, their model did not account for the different locations of the noble gas species' ice lines. In our study, we aim to develop a disk model that can explain the noble gas abundances in the Jovian atmosphere, incorporating disk photoevaporation, radial drift of species, and the different ice lines. We found that when the noble gas species are trapped only on the amorphous solid water surfaces, they can be released at more distant ice lines (19-35 K). In this case, the noble gas abundance of the disk gas has been close to the solar value in the almost entire disk region. On the other hand, when the noble gas species are trapped in the deeper amorphous ice site, they can be released at the hotter disk region (40-50 K). These closer ice lines lead to the noble gas enrichment of the disk gas inside the ice lines and hence photoevaporation occurring outside the ice lines can remove mainly the noble-gas-depleted disk gas. As a result, we can obtain the Jovian atmosphere with super-solar noble gas abundance. Our result implies the importance of the future detailed investigation on the entrapment and desorption of the noble gas species on the amorphous ice in the protoplanetary disk.

Feng Long / University of Arizona

Title: Chemical evolution in the inner region of protoplanetary disks

The chemical evolution of protoplanetary disks plays a central role in setting the initial conditions for planet formation and directly shaping the atmospheres and compositions of emerging planets. The inner few AU disk regions, where most rocky planets reside, host complex gas-phase chemistry that is best traced through mid-infrared spectroscopy. With its unprecedented sensitivity and improved spectral resolution, JWST/MIRI has opened a new era in the study of inner disk chemistry, especially in faint, low-mass star systems and evolved disks previously inaccessible to such detailed analysis.In this talk, I will review recent progress enabled by MIRI observations, highlight emerging trends in chemical diversity and evolution across different host stars and disk types, and discuss the implications for planet formation, volatile delivery, and atmospheric compositions.

Shinsuke Takasao / Musashino Art University

Title: Stellar-scale processes shaping the inner boundary conditions of protoplanetary disks

Stellar-scale processes play crucial roles in the evolution of protoplanetary disks. Ionizing radiation from stars, such as EUV and X-rays, significantly contributes to disk gas dispersal. In addition, star–disk interactions shape the density structure of the innermost disk regions, potentially influencing the orbital evolution of short-period planets. These processes collectively define the inner boundary conditions of protoplanetary disks. To investigate their properties, we have advanced both theoretical and numerical studies. We are developing models of stellar ionizing radiation that incorporate detailed magnetic heating in stellar coronae, and we are performing 3D MHD simulations to study star–disk interactions across different evolutionary stages. In this presentation, I will introduce our approach and highlight recent findings.

Tianhao Li / Tsinghua University

Title: Dust transport with local simulation of PPD

The innermost region is one of the most intriguing areas in protoplanetary disks (PPDs). At this location where irradiation is strongest and the magnetorotational instability (MRI) is active, the interplay between accretion heating and irradiation heating creates a thermal structure resembling a lasagna: the hot midplane is confined by two cold upper layers, while the uppermost surfaces are hot again. It has been shown that such a structure influences both gas chemistry and dust composition. We employed Athena++, equipped with a newly implemented M1 radiation module, to perform a shearing box RMHD simulation of the innermost PPD. Gas chemistry (ionization) and dust opacity were handled using tables derived from chemistry networks and dust models. Based on the statistically steady state obtained from the simulation, a detailed investigation of dust transport was carried out with the assistance of a modified version of ExoLyn, a Python code designed for dust sublimation and condensation. It was found that in the innermost PPD, a dust cycling mechanism can be established in the balance of sedimentation and wind uplift. The observational implications of such a cycling phenomenon will be quantitatively investigated in the future.

Ryo Kato / Institute of Science Tokyo

Title: Rocky planetesimal formation in thermally unstable inner regions of protoplanetary disks

Recent exoplanet surveys have revealed that close-in super-Earths are common in exoplanetary systems. Answering the fundamental question of where they formed requires understanding of planet formation in the innermost regions of protoplanetary disks. One plausible scenario for planetesimal formation in the inner disk regions invokes dust trapping at the pressure bump formed by the activation front of magnetorotational instability (MRI; e.g., Kretke et al. 2009; Ueda et al. 2019). However, the MRI activation front is known to be thermally unstable (Cecil & Flock 2025) and may fail to sustain the pressure bump. In this study, we examine whether planetesimals can form in thermally unstable inner disks. To this end, we have developed a self-consistent model that calculates the co-evolution of dust and temperature, along with planetesimal formation. Our results show that thermal instability induces cyclic activation and deactivation of MRI, during which planetesimals form. The dust accumulated at the MRI front reduces local cooling efficiency and forms a temperature bump that sustains the pressure bump even after MRI becomes inactive. This mechanism promotes further dust accumulation—the process we have identified as thermally driven dust accumulation (Kato et al. 2025). Planetesimals form while the dust drifts inward. The inward-moving dust cluster reduces cooling efficiency in the inner region, raises the temperature, and reactivates MRI. This cyclic process leads to repeated planetesimal formation in specific regions. In our fiducial model, planetesimals with a total mass of several Earth masses form between 0.2 and 1,au, suggesting that this process could be the origin of close-in rocky planets.

Yisheng Tu / University of Virginia

Title: Magnetic Pressure Driven Outflows: Lightly Loaded Jets and Dense Disk Winds in Protostellar Systems

Jets and outflows in young stellar objects (YSOs) play a critical role in connecting the inner disk environment with large-scale observables, yet their launching mechanisms remain poorly understood. Observations of both symmetric and asymmetric, including uni-polar, jets raise important questions about the physical processes that govern jet morphology. In our own Solar System, the discovery of refractory inclusions—such as Calcium-Aluminum-rich Inclusions (CAIs)—in meteorites originating from the outer regions suggests efficient outward transport from the hot inner disk, possibly via jets or disk winds. To investigate these processes, we conduct non-ideal MHD simulations that naturally give rise to three distinct outflow components: (1) a fast, magnetically driven jet along the rotation axis; (2) an MRI-active turbulent disk wind at intermediate cylindrical radii; and (3) a slower, laminar disk wind at larger radii. At high altitudes (beyond ∼1,au), the turbulent disk wind merges with the laminar component, leaving only the distinction between the jet and the disk wind. We find that jets are lightly mass-loaded and launched by toroidal magnetic pressure, bridging features of both classical magneto-centrifugal and magnetic tower models. Crucially, whether MRI-driven turbulent winds fill the polar region and suppress jet launching in one hemisphere, thereby producing asymmetric or uni-polar jets, depends on the interplay between the stellar magnetosphere and the large-scale disk magnetic field. In cases where the disk field dominates, jets are more likely to be one-sided; conversely, a strong, rotating stellar magnetosphere suppresses polar MRI activity and facilitates the launching of symmetric, bipolar jets. This sensitivity to magnetic field topology provides an observational handle for probing the relative roles of stellar and disk magnetism. Furthermore, the denser and slower disk wind offers a natural mechanism for the outward transport of CAIs, potentially explaining the observation of high-temperature inclusions in early Solar System materials.

Yukun Huang / NAOJ

Title: An Analytical Solution for Planet-Scattering Small Bodies

Gravitational scattering of small bodies (planetesimals) by a planet remains a fundamental problem in celestial mechanics. It is traditionally modeled within the circular restricted three-body problem (CR3BP), where the dynamics are deterministic and individual particle trajectories are obtained via numerical integration. The extreme sensitivity of orbital-element changes to the precise encounter distance and geometry leads to chaotic scattering behavior, and the singularity in the planetary potential for orbit crossings precludes solutions based on perturbative expansions or mapping approaches. Here, we introduce a patched-conic framework to describe the collective scattering of an ensemble of test particles on planet-crossing orbits. We show that the evolution of each particle's orbital elements (a, e, i) is fully encapsulated by the motion of the relative velocity vector, which, when expressed in two degrees of freedom (x, ϕ), has constant magnitude. By averaging over all possible flyby geometries, we derive explicit expressions for the drift and diffusion coefficients of the normalized orbital-energy variable x. We then solve the resulting Fokker-Planck equation to obtain a closed-form solution for the time evolution of the particle distribution. A characteristic scattering timescale naturally emerges, scaling as $(P_\mathrm{p}/M_\mathrm{p}^2)/500$, where P_p is the planet's orbital period and M_p its mass ratio relative to the central star. Our analytical solution constitutes a universal law applicable to the Solar System and exoplanetary systems alike, providing a computationally efficient alternative to costly N-body simulations for studies of orbital distributions and ejection of planetesimals (e.g., Kuiper Belt, Oort Cloud, debris disks, and interstellar objects).

Chris Ormel / Tsinghua University

Title: A Resonant Beginning for the Solar System Terrestrial Planets

In the classical formation scenario, Earth formed late through a series of chaotic collisions among Mars-sized embryos and planetesimals, following the dispersal of the Solar System's gaseous disk. This view contrasts with observations of exoplanets, where many planets just above Earth in mass are found to retain hydrogen- and helium-rich envelopes, indicating early formation in gas-rich environments. If planets form in disks, it is expected that orbital migration traps planets into mean-motion resonances, with the planet's orbital periods following simple ratios. While there are only a handful of systems currently exhibiting resonance chains, there is growing evidence that planets emerge from the disk phase in resonance. Here, we hypothesize that the Solar System's terrestrial planets initially constituted such a resonance chain. By conducting numerical (N-body) experiments, we demonstrate that dynamical perturbations from the outer giant planets are sufficient to disrupt the primordial resonance chain and that a Solar System analogue can emerge with reasonably high probability. Our model naturally accounts for several key features: the near 3:1 period ratio between Venus and Mars, the timing and impact parameters inferred for the Moon-forming event, and the present-day eccentricities and inclinations of the terrestrial planets. These findings suggest that the Solar System's terrestrial planets formed early – more akin to exoplanets than traditionally thought.

Masahiro Ogihara / SJTU

Title: A coherent model for the formation and period ratio evolution of super-Earth systems

Observations by the Kepler and TESS space telescopes suggest that super-Earths were likely captured into mean-motion resonances during their formation, but these resonances were often disrupted over the subsequent 100 million years. In this study, we investigate whether such long-term evolution of period ratios in super-Earth systems can be reproduced by planet formation simulations. Specifically, we perform N-body simulations to model the formation and evolution of super-Earths from a ring of protoplanets. The simulations cover several million years of evolution in a protoplanetary gas disk, followed by 100 million years of dynamical evolution after disk dispersal. Our results show that, in almost all cases across a wide range of initial conditions, super-Earths form in resonant chains during the gas disk phase. In some cases, however, dynamical instabilities arise after disk dispersal, leading to the disruption of these resonant configurations. When such instabilities occur, the time evolution of period ratios resembles those observed in exoplanet systems. Motivated by these findings, we further examine the origin of the resonance-breaking instabilities. Our analysis suggests that secular perturbations from leftover planetary embryos, which are formed as byproducts of super-Earth formation, can destabilize the inner resonant chains on approximately 100 million-year timescales. We confirm this interpretation through analytical arguments and additional orbital simulations.

Qingru Hu / Tsinghua University

Title: A coherent model for the formation and period ratio evolution of super-Earth systems

Sednoids are extremely distant Trans-Neptunian Objects (TNOs) with large semi-major axes and large perihelion distances. To date, we have only discovered three Sedniods: (90377) Sedna, 2012 VP113, and (541132) Leleakuhonua. Sednoids are thought to have formed through a combination of early planetary scatterings, which increased their semimajor axes, and additional perturbations beyond the four giant planets, which elevated their perihelion distances. Understanding the formation mechanism of sednoids is of great significance to our understanding of the early dynamical evolution of our solar system. One hypothesis posits that close stellar flybys could have perturbed objects from the primordial scattering disk, generating the sednoid population. In this study, we run 768 N-body simulations with different stellar encounter configurations to explore whether such a close stellar flyby can satisfy new constraints identified from sednoid (and detached extreme TNO) observation, including the low-inclination ($i < 30^\circ$) profile and the primordial orbital alignment. Our results suggest that flybys with field stars are unable to generate a sufficient population, whereas flybys within the birth cluster fail to produce the primordial orbital alignment. To meet the inclination constraint of detached extreme TNOs, flybys have to be either coplanar ($i_\star \sim 0^\circ$) or symmetric about the ecliptic plane ($\omega_\star \sim 0^\circ$, $i_\star \sim 90^\circ$). After taking into account their occurrence rate at the early stage of the Solar System, we conclude that stellar flybys that satisfy all constraints are unlikely to happen ($< 5\%$). Future discoveries of additional sednoids with precise orbital determinations are crucial to confirm the low-inclination tendency and the primordial alignment, and to further constrain models of the Solar System's early dynamical evolution.

Zhecheng Hu / Tsinghua University

Title: Unexpected Near-Resonant and Metastable States in Young Multi-Planet Systems

The young planetary systems are expected to be locked in mean-motion resonance according to disk-driven planet migration models. In this talk, I will investigate the dynamical states of three of the youngest transiting multi-planet systems: AU Mic (3-planet, ~20-Myr-old), V1298 Tau (4-planet, ~23-Myr-old), and TOI-2076 (4-planet, ~200-Myr-old). Nearly all of the planet pairs involved in these systems are in near-resonant states with circulating rather than librating resonant angles. The observed system architectures are vulnerable to dynamical excitation, such as divergent resonance encounters induced by planetesimal scattering. While this near-resonant state may represent a transitional phase linking young and mature planetary systems, the evolutionary pathway to this configuration remains unclear. The implications of our results are discussed in the context of the so-called "break-the chains" model.

Hongping Deng / SHAO

Title: Gravitationally instability in circumstellar disks

Young circumstellar disks are relatively massive and subject to gravitational instability, which manifests as spiral density waves, playing a key role in angular momentum transport. The spiral density waves may fragment and form gas clumps. However, it is yet unclear how common this process is and whether the clumps are of planetary masses. To that end, we performed a series of radiation hydrodynamics simulations with the M1-closure, confirming that spiral density waves can fragment in realistic disk environments and form Jupiter-mass planets. On the other hand, interactions between young circumstellar disks can bring stable disks to instability, forming unbound planetary mass objects (PMOs). These free-floating planetary mass objects feature extended disks which may form miniature planetary systems around PMOs.

Yang Ni / Tsinghua University

Title: Direct Formation of Gas Giants via Disk Fragmentation in 3D Radiation Hydrodynamic Simulations

Gravitational instability (GI) remains a promising yet debated pathway for giant planet formation in protoplanetary disks (PPDs), especially at wide orbital separations or around low-mass stars where core accretion faces significant challenges. However, two key uncertainties remain: under what conditions GI leads to disk fragmentation, and whether the resulting fragments can form gas giants without becoming overly massive. To address these questions, we conduct a suite of global three-dimensional radiation hydrodynamics (RHD) simulations of self-gravitating PPDs using the meshless finite-mass (MFM) method. Our simulations systematically vary disk mass and opacity, solving the radiation transport equations via the M1 closure scheme. We show that both increasing disk mass and lowering opacity promote fragmentation by enhancing radiative cooling. Non-fragmenting disks settle into a gravito-turbulent state with low-order spiral structures and effective angular momentum transport characterized by $\alpha \sim 10^{-1}$. In fragmented runs, we identify and track gravitationally bound clumps and find that a subset survive as long-lived fragments. The initial masses of these fragments range from $\sim$0.3–$10, M_\mathrm{J}$, consistent with the formation of gas giants. Normalizing by an analytic mass estimate based on local disk properties yields a universal, dimensionless distribution across simulations, suggesting that fragment masses are governed by local gas conditions. Our results demonstrate that under favorable cooling conditions, GI can produce planet-mass fragments in realistic RHD simulations. This reinforces GI as a viable formation channel for gas giants and lays the groundwork for future studies on fragment survival, migration, and observational signatures.

Jiachen Zheng / Beijing Normal University

Title: Turbulent infall onto class 0 disks as cause of CAI brief condensation episode in the solar system
Calcium-aluminum-rich inclusions (CAIs) in carbonaceous chondritic meteorites are the oldest relics in the solar system. Notably, their radiogenic ages feature a brief (∼100 kyr) condensation episode. In contrast, the reservoirs of the short-lived isotopes in CAIs, presumably supernovae or asymptotic giant stars, pollute star-forming regions in giant molecular cloud complexes (GMC) over much longer (Myr) durations. Through a series of numerical simulations, we show here the possibility that "pre-solar" CAI-loaded grains in the infall clouds, if any, were sublimated and re-condensed, within an extended region (2–3 AU), during the early ($\lesssim 10^5$ yr) infall and formation of class-0 disks. We adopt a set of initial conditions from a previous hydrodynamic simulation of the collapse of GMC and the formation of young stellar clusters. We analyze the evolution of the disk's thermal distribution and dynamical structure resulting from the interaction between circumstellar disks and infalling gas. Our follow-up simulations, with much higher resolution, show significant and rapid changes in the disk orientation and morphology due to the dynamic infall of external streamers. Warps and global spiral density waves commonly appear. They lead to intense dissipation which heats the gas to sufficiently high temperature to sublimate prior-generation CAIs. This solid-to-gas phase transition is followed by subsequent cooling and re-condensation. The CAIs contained in the meteorites today are the relics of the last episode of major infall onto class 0 disks.

Wei Zhu / Tsinghua University

Title: Giant planets are lonelier than expected
Extrasolar gas giants typically have eccentric orbits. The leading explanation is that these planets have gone through planet-planet scatterings and survived. To reproduce the observed eccentricity distribution, multiple giants would survive in the end. Using exoplanet samples from two leading radial velocity (RV) surveys, I show that the giant planet multiplicity is not as high as expected. This suggests that other mechanisms may need to be considered to excite the orbital eccentricities. The inconsistencies between different RV surveys and the implications will also be briefly discussed.

Sharon Xuesong Wang / Tsinghua University

Title: Search and Characterize Earth-like Planets with CHORUS
CHORUS (Canary Hybrid Optical high-Resolution Ultra-stable Spectrograph) is a next-generation extreme precision radial velocity instrument for the 10-meter Gran Telescopio Canarias, designed to reach $10, \mathrm{cm}, \mathrm{s}^{-1}$ precision. CHORUS features a dual-arm design with a UV arm (310–420, nm, $R \sim$ 25,000) and a visual arm (420–780, nm, $R \sim$ 120,000). The expected science programs include PRV surveys of nearby stars, follow-up of transit discoveries, characterization of exoplanet atmospheres, finding stars with primordial composition, and galactic archaeology. I will introduce the ongoing precursor science programs focusing on refining target selection and mitigating stellar activity to improve detection sensitivity, and we invite the community to join these efforts in preparation for the science operation starting in 2028.

Yaxing He / SJTU

Title: Impact-Driven Atmospheric Mass Loss in Sub-Neptune Systems: Origins of the Radius Gap and Its Intermediate Planets

The radius gap in sub-Neptunes, which indicates a deficit in planet occurrence between about 1.5 and 2 Earth radii, has attracted a lot of attention over the past five years in exoplanet studies. Some previous studies consider atmospheric escape from sub-Neptunes through photoevaporation or core-powered mass loss to explain the observed bimodal distribution in the size of planets. According to theoretical models, as a byproduct of sub-Neptune formation residing at about 0.1–1 au from the star, planetary embryos with high eccentricity can remain in outer orbits about 1 au. These outer planetary embryos can collide with sub-Neptunes, leading to atmospheric loss through impact erosion. In this study, we examine the long-term evolution of systems consisting of close-in sub-Neptunes and outer high-eccentricity embryos. Specifically, we aim to quantify the impact velocities between these two populations and the resulting atmospheric loss through such collisions. Additionally, we explore how initial conditions, including the eccentricity and number of embryos, influence the final radius distribution of sub-Neptunes. We utilize N-body methods to model the 50 Myr dynamics of the planetary system consisting of three close-in sub-Neptunes at 0.15–0.45 au, separated by a distance of 30 times their mutual Hill radius, and planetary embryos uniformly distributed in a two-dimensional space between 1–2 au. We perform a series of simulations with varying initial numbers of planetary embryos, ranging from 60 to 100, and different initial eccentricities, ranging from 0.7 to 0.9. Our results show that sub-Neptunes can experience high-speed collisions, with impact velocities 2–5 times the escape velocity of the sub-Neptunes, leading to substantial atmospheric loss. On average, approximately 15–30% of the atmosphere is dissipated per collision, so after about 3–6 collisions, the atmospheric mass of sub-Neptunes is reduced to about one-third of their initial atmospheric mass, effectively explaining the presence of planets within the radius gap. Depending on the initial eccentricity and the number of remaining embryos, additional collisions can occur, potentially accounting for the formation of the radius gap. Our study also has implications that collisions between remaining embryos and sub-Neptunes may help explain the observed rarity of sub-Neptunes with atmospheric mass fractions greater than 10%, commonly referred to as the radius cliff. Keywords: Sub-Neptunes, Radius gap, Atmospheric loss, N-body simulation, Impact erosion.

Quanyi Liu / Tsinghua University

Title: Transiting super Earths in known RV systems and the implication to the inner-outer correlation

Extrasolar gas giants typically have eccentric orbits. The leading explanation is that these planets have gone through planet-planet scatterings and survived. To reproduce the observed eccentricity distribution, multiple giants would survive in the end. Using exoplanet samples from two leading radial velocity (RV) surveys, I show that the giant planet multiplicity is not as high as expected. This suggests that other mechanisms may need to be considered to excite the orbital eccentricities. The inconsistencies between different RV surveys and the implications will also be briefly discussed.

Di Wu / NJU

Title: Planets Across Space and Time (PAST). VIII: Kinematic Characterization and Identification of Radial Velocity Variables for the LAMOST-Gaia-TESS Stars

The Transiting Exoplanet Survey Satellite (TESS) has discovered over 6700 nearby exoplanet candidates using the transit method through its all-sky survey. Characterizing the kinematic properties and identifying variable stars for the TESS stellar sample is crucial for revealing the correlations between the properties of planetary systems and the properties of stars (e.g., Galactic components, age, chemistry, dynamics, radiation). Based on data from TESS, Gaia DR3, and LAMOST DR10, we present a catalog of kinematic properties (i.e., Galactic positions, velocities, orbits, Galactic components, and kinematic age) as well as other basic stellar parameters for 660,000 TESS stars. Our analysis of the kinematic catalog reveals that stars belonging to different Galactic components (i.e., thin disk, thick disk, halo and 12 streams in the disk) display distinctive kinematic and chemical properties. We also find that hot planets with periods less than 10 days in the TESS sample favor thin disk stars compared to thick disk stars, consistent with previous studies. Furthermore, using the LAMOST multiple-epoch observations, we identify 41,445 stars exhibiting significant radial velocity variations, among which 7,864 are classified as binary stars. By fitting the radial velocity curves, we further derive orbital parameters (e.g., mass ratio, orbital period and eccentricity) for 297 binaries. The catalogs constructed in this work have laid a solid foundation for future work on the formation and evolution of stellar and planetary systems in different Galactic environments.

Haifeng Yang / ZJU

Title: Millimeter disk polarization from protoplanetary disks

Millimeter disk polarization is an exciting new field of research that has been revolutionized by ALMA. In contrast to the canonical picture of magnetic alignment, the (sub)millimeter disk polarization from protoplanetary disks come from mostly the self scattering of dust grains, especially at shorter ALMA bands. Going towards longer wavelengths, the polarization patterns show multiple origins. In this talk, I will review our current understanding on the origins of disk polarizations across ALMA bands, and how we can use disk polarization to study the environment and dust properties in the protoplanertary disks.

Chin-Fei Lee / ASIAA

Title: Polarization Substructure in the Spiral-dominated HH 111 Disk: Evidence for Grain Growth

The HH 111 protostellar disk has recently been found to host a pair of spiral arms. Here we report the dust polarization results in the disk as well as the inner envelope around it, obtained with the Atacama Large Millimeter/submillimeter Array (ALMA) in continuum at λ = 870 m and $\sim$0.05 resolution. In the inner envelope, polarization is detected with a polarization degree of $\sim$6% and an orientation almost everywhere parallel to the minor axis of the disk, likely due to dust grains magnetically aligned mainly by toroidal fields. In the disk, the polarization orientation is roughly azimuthal on the far side and becomes parallel to the minor axis on the near side, with a polarization gap in between on the far side near the central protostar. The disk polarization degree is $\sim$2%. The polarized intensity is higher on the near side than the far side, showing a near-far side asymmetry. More importantly, the polarized intensity (and thus polarization degree) is lower in the spiral arms but higher in between the arms, showing an anticorrelation with the spiral arms. Our modeling results indicate that this anticorrelation is useful for constraining the polarization mechanism and is consistent with dust self-scattering by grains that have grown to a size of $\sim$150 m. The interarm regions are sandwiched and illuminated by two brighter spiral arms and thus have higher polarized intensity. Our dust self-scattering model can also reproduce the observed polarization orientation parallel to the minor axis on the near side and the azimuthal polarization orientation at the two disk edges along the major axis. Further modeling work is needed to study how to reproduce (1) the observed near-far side asymmetry in polarized intensity, and (2) the observed azimuthal polarization orientation on the far side.

Haochang Jiang / MPIA

Title: Diverse Planet-Forming Chemistry in Herbig Disks of the Taurus Star-Forming Region

Sulfur, carbon, and oxygen are key elements that underpin the formation of complex molecules and organics in protoplanetary disks. Elemental ratios such as C/O and S/O have long been proposed as powerful diagnostics for tracing the formation history and chemical environments of mature planets. Herbig stars—pre-main-sequence stars with masses above 1.5 $M_{\odot}$—are recognized as prime sites for giant planet formation, yet their disk chemistry remains less explored compared to lower-mass T Tauri stars. In this talk, I will present our recent efforts to characterize the chemical inventory of Herbig disks in the Taurus star-forming region using ALMA and NOEMA observations. We report the detection of SO emission in two spiral-hosting disks, pointing to a strong connection between sulfur chemistry and dynamical perturbations. In a triple-star system, we identify a prominent CCH ring, indicative of a carbon-rich environment. Lastly, we observe significant azimuthal asymmetries in both SO and CCH emissions in another disk, highlighting the influence of environmental interactions on disk chemistry. These findings reveal the chemical diversity of Herbig disks and provide new insights into the physical and chemical processes that govern planet formation.

Naoya Kitade / NAOJ

Title: Numerical solutions of radiative transfer in a parallel-slab incorporating millimeter wavelength scattering polarization for protoplanetary disks

Planets form through the coagulation and growth of dust grains within protoplanetary disks. To unravel this growth process observationally, it is crucial to determine the dust properties, specifically dust size and porosity, within the disk. Traditionally, these properties have been inferred from millimeter-wavelength spectral energy distribution (SED) analyses. In optically thick regions, where dust scattering significantly affects the emission, observers have applied approximate formulae (e.g., Miyake & Nakagawa 1993; Birnstiel et al. 2018; Sierra et al. 2019; Carrasco-Gonzalez et al. 2019; Zhu et al. 2019) to interpret the data. Millimeter-wave polarization observations have also been used to constrain dust properties. However, deriving dust size and porosity from polarization requires comparing observations to Monte Carlo radiative transfer simulations, which carries a substantial computational cost. In this work, we numerically solve the radiative transfer equation for a plane-parallel slab, including scattering and polarization, to derive the emergent intensity and polarization fraction from the slab. First, we compare the emergent intensity with the approximate formulae, which have been used previously, to assess their accuracy. We find that the approximate formula deviates from our derived emergent intensity by roughly 10%. Next, we further analyze the polarization components of our numerical solution. Fitting our numerical polarization fractions, we develop an empirical formula to express the polarization fraction as a function of the disk inclination, the dust albedo and the optical depth of the slab. This new formula provides a fast and accurate way to interpret millimeter-wave polarization data. As a result, our framework opens the door to rapid and precise constraints on dust size and porosity from both continuum SEDs and polarization data.

Yinhao Wu / University of Leicester

Title: Planets Migration in Turbulent Environment

We investigate the impact of disc turbulence on the formation and survival of mean-motion resonances (MMRs) during planetary migration, using global hydrodynamical simulations of low-mass planets embedded in protoplanetary discs. When turbulence is weak, planets can robustly capture into resonances such as the 3:2, with resonance stability largely insensitive to laminar viscosity over a wide range. However, strong turbulence induces stochastic torques and disrupts classical Type I migration, driving chaotic orbital evolution and enhancing the overstability of resonant libration. This leads to premature resonance escape and promotes tighter orbital configurations, such as 4:3 or 5:4 resonances. We identify a turbulence-driven transition from classical to chaotic migration, characterized by a threshold mass ratio scaling with the Reynolds stress parameter. These results suggest that active disc turbulence broadens the conditions under which MMRs are bypassed or broken, reducing the frequency of long-lived resonant chains and potentially suppressing three-body interactions. Our findings are consistent with recent TESS observations showing that younger systems more frequently exhibit resonant configurations, whereas older systems display wider period ratio dispersions than can be explained by turbulent migration alone. Additional post-disc dynamical processes are likely required to fully reproduce the observed spread.

Bingjie Zha / Freie Universitat Berlin

Title: Modeling Planetary Accretion Shocks with a Realistic Equation of State and a Physics-Informed Neural Network

Gas giants accumulate most of their mass during the runaway gas accretion stage, during which the infalling gas forms strong shocks exterior to the planetary surface. The post-shock states profoundly influence the subsequent evolution and the initial thermodynamic structure of young gas giants. To investigate the physics and outcomes of accretion shocks, we perform thousands of simulation using Guangqi with a realistic equation of state (EoS) incorporating H2 dissociation. Our simulations systematically cover a wide parameter space including planetary mass and radius, accretion rate, and the internal luminosity of forming gas giants, with explicit focus on post-shock properties (entropy, temperature and H2 dissociation). Furthermore, we develop a physics-informed neural network (PINN) trained on the simulation results. The trained PINN model can instantaneously predict post-shock states with excellent performance (R^2 score > 0.99, MAPE $\leqslant 1\%$). This enables the model to provide realistic boundary conditions at runtime for interior evolution simulations, such as those in MESA, improving studies of gas giant formation. A comprehensive parameter survey using the PINN model reveals that H_2 dissociation is more likely to occur around compact (<1.6 $R_\odot$) and massive planets (>0.5 $M_\odot$) with high accretion rates (>1×10^{-5} $M_\odot$/yr).

Junpeng Pan / SHAO

Title: Concurrent Accretion and Migration of Giant Planets in Protoplanetary Disks

Migration commonly occurs during the epoch of planet formation. For emerging gas giant planets, it proceeds concurrently with their growth through the accretion of gas from the protoplanetary disks. In classical theories of planetary migration, both Type I and Type II processes result in fast inward migration, which is hard to align with the architecture of the planetary systems. Recent works found that the accretion plays an important role in the dynamical evolution of the planet. In this work, we conducted systematic, high-resolution 3D hydrodynamic numerical simulations to investigate the migration of accreting planets. The effect of different planet masses, disk parameters are systematically explored. Our findings show that planetary accretion can weaken the inward tendency, or even reverse it to outward across a broad range of parameter space. We will also discuss the observational implications of our simulation results for planetary evolution.

Shizu Shimizu / Institute of Science Tokyo

Title: The Effect of Shock Heating Induced by Giant Planets on the Location of the Snow Line in Protoplanetary Disks

It is widely believed that rocky planets, such as Earth, formed inside the snow line, the orbital distance at which water ice sublimates. Therefore, determining the temperature structure of the protoplanetary disk is crucial for understanding the formation locations of rocky planets. This study focuses on shock heating induced by giant planets. A planet within a protoplanetary disk excites spiral density waves through gravitational interaction with the disk. As these density waves propagate, they develop a shock, heating the disk. Shock heating can be comparable to classical viscous heating (Ziampras et al. 2020). Ono et al. (2025) calculated the shock heating rate by measuring the increase in entropy across planet-induced spiral shocks. However, the shock heating rate in the region well interior to the giant planet's orbit has not been investigated. In this study, we investigate the extent to which the snow line shifts due to shock heating from a giant planet in two steps. First, we perform 2D hydrodynamical simulations of a disk with a giant planet, extending the simulation domain further inward, to measure and model the shock heating rate. Second, we calculate the radial temperature distribution of the disk using the modeled heating rate. The results of the 2D hydrodynamical simulations confirm the existence of five spiral arms in the region interior to the giant planet. The total heating rate can be approximated by a simple power function of the distance from the planet's orbit and its mass. Our disk temperature model calculation reveals that a planet with about one-tenth the mass of Jupiter, located at 5,au, pushes the snow line's position beyond 1,au. This implies the importance of shock waves that propagate far from the giant planet. It also suggests that the early formation of Jupiter in the solar nebula could have enabled the formation of rocky planets at Earth's current orbit, even without classical viscous heating.
