NEW HORIZONS IN PLANETARY SYSTEMS

13-17 MAY, 2019 | VICTORIA, BC

Poster Presentation Abstracts

Abedin Abedin (NRC-HAA)

JJ. Kavelaars (NRC - HAA)

Topic: Solar System Dynamics

Collisional Speeds and Probabilities in the Kuiper Belt, Based on the OSSOS Model

We present results on the collision probability and speeds of classical Kuiper Belt Objects (KBOs) onto the NASA New Horizons (NH) target Ultima-Thule (2014 MU_{69}). The latter is a classical KBO, belonging to the "cold" subpopulation of bodies orbiting the Sun on relatively low inclination and eccentric orbits, compared to the "hot" KBOs. We use the Outer Solar System Origin Survey (OSSOS) of the Kuiper belt to calculate the collision probability between different KBO populations and onto 2014 MU_{69}.

The goal of this study is to constrain the collision frequency between different KBO orbital classes, with implication of dust production rate, as a function of the distance from the Sun, due to their disruption. Understanding the latter process and the dynamical evolution of the dust in the Kuiper belt is critical for deriving a comprehensive model of the formation mechanisms of planetary rings and cratering processes onto KBOs. Moreover, having information on the impact probability and speeds with respect to 2014 MU_{69} is relevant to the formation of different (contact, close or wide) binary systems in the Kuiper belt, which is pivotal to deciphering the formation and dynamical evolution of 2014 MU_{69}.

Our modelling involves backward numerical integration for 10^7 years of the orbits of 1.6×10^6 classical KBOs, derived from the Outer Solar System Origin Survey (OSSOS) model of the trans-Neptunian region. Then the past orbital distribution is used to calculate the collision probability between each KBO subpopulation and the impact rates onto 2014 MU_{69}, arising from bodies belonging to each population. In addition, we also compute the impact speeds in order to estimate the energy and outcome of the collision.

We find that the "cold" classical KBOs dominate the impact rate onto 2014 MU_{69}, followed by the "hot" and "warm" populations, where the latter is a subpopulation of the "hot" ensemble of KBOs. Furthermore, the collision speeds for the "cold" KBOs range from a V~ 0.1-1 km/s, with a peak near V=400 m/s. In contrast, the "hot" population seems to be impacting 2014 MU_{69} with a mean value near 1.5-2 km/s, followed by the "warm" subgroup of KBOs which tend to impact with mean speed V~1 km/s.

Mike Alexandersen (Academia Sinica Institute of Astronomy and Astrophysics (ASIAA))

Rosemary Pike (ASIAA)
Yeeun Hyun (ASIAA Summer Student Program)
Ashwani Rajan (ASIAA Summer Student Program)

Topic: Solar System

The Color Distribution of the Plutinos: Size and Inclination Dependent

The Plutinos, in 3:2 resonance with Neptune, have a color distribution which depends on both inclination and object size. The *g-r* colors of 15 Plutinos discovered in the Alexandersen et al. (2016) survey, show that the small ($H_r > 8.4$) objects have a different color distribution than the larger Plutinos ($5.5 < H_r < 8.4$) at 95% confidence. This suggests that the small objects have a different formation mechanism than the large objects, possibly being primarily collisional fragments. The low-inclination and high-inclination (divided at about 6°) also show different color distributions at 95% confidence. The excess of red surfaces at low inclinations suggests that the Plutino population is contaminated by captured objects of cold classical origin. Our color distribution model including both an *H*-dependent color distribution and an additional red low-inclination component produced the highest likelihood of the models we considered. Based on our measurements, we estimate the true (unbiased) color-ratio of Plutinos of different sizes and inclinations. We propose that the abundance of low-inclination red Plutinos requires that the formation region of the cold classicals extended inward of 39 AU.

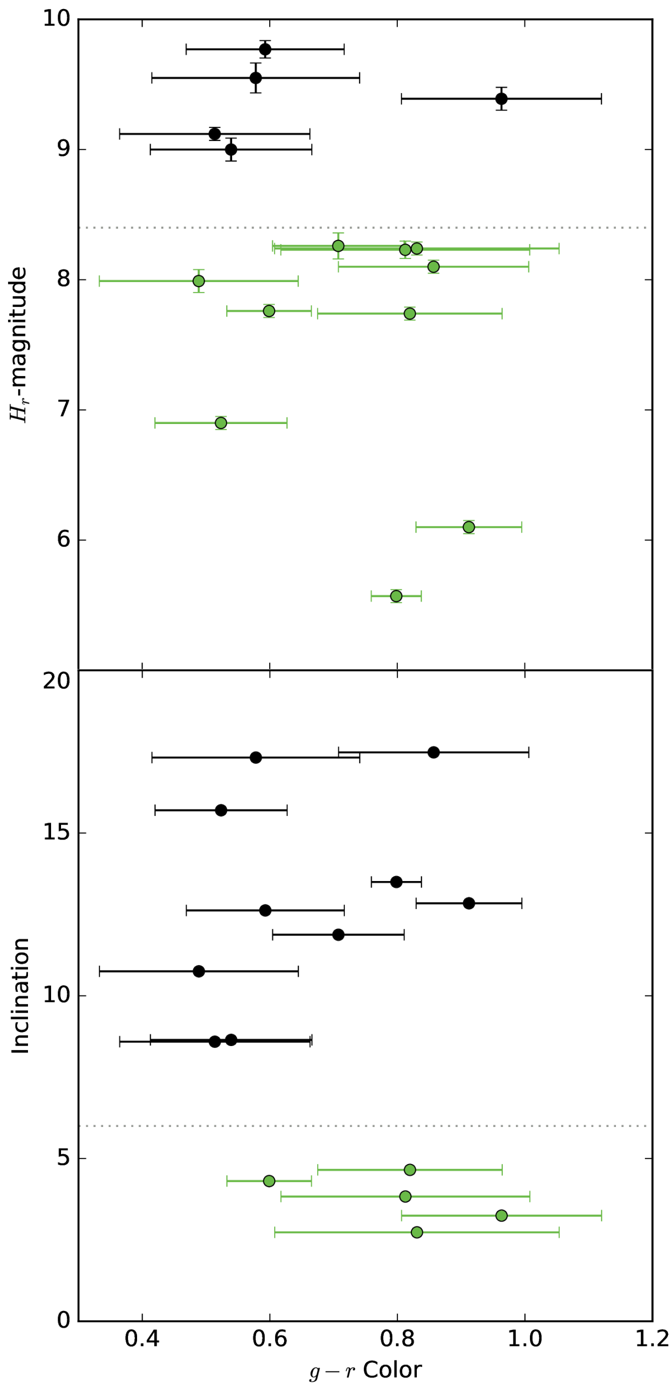

Figure 1: H_r magnitude (top) and inclination (bottom) versus *g-r* color for 15 Plutinos. The sub-populations above and below the dotted lines have color distributions that are different at 95% confidence. The dotted line in the top panel corresponds to the known transition in the size distribution of this population (Alexandersen et al. 2016) and in the bottom panel corresponds to the typical division between dynamically 'hot' and 'cold'. This suggests that both size and inclination affect the color distribution of the Plutinos.

Mohamad Ali-Dib (iREx / University of Montreal)

Topic: Solar System

The Origins of the Colors-Inclinations Correlation in Hot TNOs

We present new n-body simulations for the formation and evolution of the Kuiper belt, that simultaneously tracks the chemical composition of objects. We show that the colors-inclination correlation observed in the hot and resonant TNOs populations by the COL-OSSOS survey (Marsset et al. 2018) is a natural outcome of the physical-chemical processes that shaped the early outer solar system.

Jessica Arnold (Carnegie DTM)

Alycia Weinberger (Carnegie DTM)
Gorden Videen (Space Science Institute)
Evgenij Zubko (Far Eastern Federal University)

Topic: Debris Disks

Exploring Debris Disk Composition with Light Scattering Models and Laboratory Measurements

Debris disks contain dust generated by collisions and disruptions of protoplanets and/or planetesimals that are analogous to asteroids and comets in our own solar system. Our goal is to ascertain the composition of the material within these extrasolar systems in order to better understand the planet formation process. Maximizing the utility of data from telescopic facilities for understanding debris disk dust composition requires more accurate models of the light scattering properties of dust. Dust grains within debris disks likely exhibit a variety of complex, porous structures comparable to dust within our own solar system. We use the Zubko et al. [2010] implementation of the discrete dipole approximation (DDA) method to calculate the light-scattering properties of irregularly shaped agglomerated dust grains (Figure 1). We explore the implications of this model for the interpretation of spectrophotometric data. Another component of improving light scattering models is having accurate measurements of the wavelength-dependent index of refraction for a variety of relevant materials. We present such measurements for a solar system organic analog material (Figure 2).

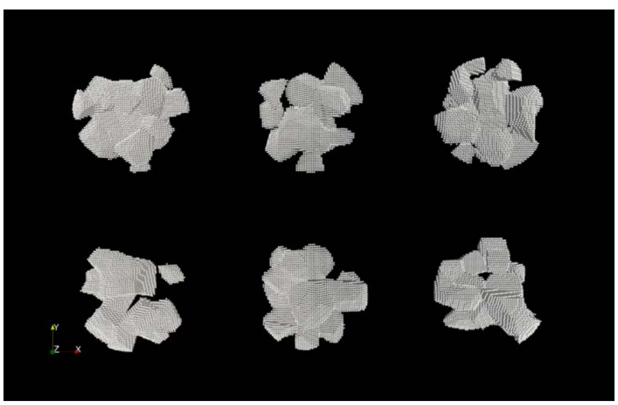

Figure 1: Six examples of agglomerated dust grains. These were generated with lattice dimensions of 2563 dipoles, which was cut down to 643 dipoles for rendering purposes. This type of particle has an average porosity of 76.4%.

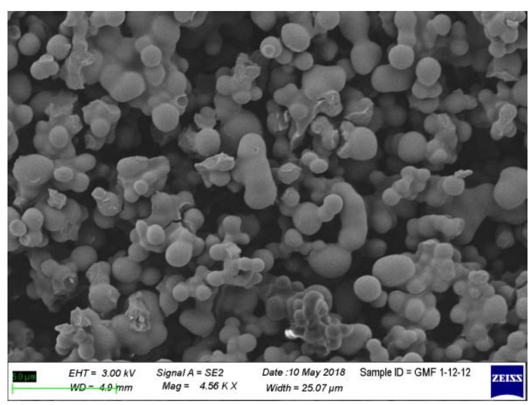

Figure 2: SEM images of the laboratory synthesized formaldehyde-derived polymer sample.

Giulia Ballabio (University of Leicester)

Richard Alexander (University of Leicester)

Topic: Protoplanetary Discs

Empirical Diagnostics of Protoplanetary Disc Winds

Disc winds play an important role in the evolution of protoplanetary systems, with photoevaporative winds in particular thought to be responsible for gas disc dispersal at late times. We present a new study of the observable diagnostics of these disc winds. We use both semi-analytic and numerical hydrodynamic models of disc winds, and compute observables such as free-free and forbidden line emission. We focus in particular on spatially-resolved observations (radio interferometry and optical/IR spectro-astrometry), and show how these techniques may allow us to measure disc mass-loss rates empirically. When combined with new observations (particularly from the VLT), these new diagnostics will allow us to build up a complete picture of how disc winds shape the evolution of planet-forming discs.

Mark Booth (Friedrich Schiller University, Jena)

Fabian Geiler (Friedrich Schiller University, Jena)
Alexander Krivov (Friedrich Schiller University, Jena)
Torsten Löhne (Friedrich Schiller University, Jena)

Topic: Debris Disks

The Scattered Disc of HR 8799

HR 8799 is a young early-type star with four directly imaged giant planets and two debris belts, one located exterior and another one interior to the region occupied by the planets. This unique combination makes it a key system for testing formation and evolution models of planetary systems and has led to the debris disc being imaged by a multitude of instruments from infrared to millimetre wavelengths. Previous modelling of the outer disc has been done empirically, and the far-infrared and millimetre data have not previously been modelled simultaneously. In this work we simultaneously model both the Herschel and ALMA data for the first time using a physical model that includes collisions, transport forces and realistic grain properties. We demonstrate that the previously proposed model of a low-eccentricity planetesimal belt and a radiation pressure induced dust halo cannot account for the observed radial brightness profiles. Instead, we propose a two-population model, comprising a Kuiper-Belt-like structure of a low-eccentricity planetesimal population ("the classical Kuiper Belt") and a high-eccentricity population ("scattered disc"). We argue that such a structure of the exo-Kuiper belt of HR 8799 could be explained by the proposed fifth planet in the system or with planet migration scenarios analogous to those proposed for the Kuiper Belt of the Solar System, provided migration occurred before the planet cores accreted their gas envelopes. We propose that scattered discs, such as HR 8799's, could be a common feature, naturally explaining why many debris discs appear radially broad even when observed at millimetre wavelengths.

This research was conducted under the framework of the Research Unit FOR2285: "Debris Disks in Planetary Systems" funded by the German Research Association (DFG), grants Kr 2164/13-1, Kr 2164/15-1, and Lo 1715/2-1.

Josh Calcino (University of Queensland)

Daniel Price (Monash University)
Christophe Pinte (Monash University)

Topic: Protoplanetary Disks

Signatures of an Eccentric Disk: Dust and Gas in IRS48

Observations of protoplanetary disks at multiple wavelengths have revealed spectacular disk morphologies, including spiral arms, circular and eccentric dust cavities, and azimuthally asymmetric dust horseshoes. All these can be caused by the interaction of companions, of planetary or stellar mass, embedded within the disk. Using numerical simulations, I have been exploring how changing the properties of a companion in a disk changes the disk morphology.

By including a stellar companion, I have found it is possible to create dust horseshoes with high contrast ratio, as observed in IRS48, without vortexes. Although no high mass companion has yet been confirmed in this disc, I will show how a companion with mass on the order of 0.4 Msun can explain the dust trap, and the asymmetric CO kinematics in this disc. My results indicate that asymmetrical dust horsehoes are the result of dynamical interactions between the host star, the companion, and the disc. These results bring in to question the common interpretation that dust traps in protoplanetary discs are caused by large scale vortexes, which has consequences for some planet formation hypotheses. This interpretation makes clear predictions about the CO kinematics of the IRS48 which may be detectable with ALMA.

Cheng Chen (University of Nevada, Las Vegas)

Rebecca Martin (University of Nevada, Las Vegas)
Steve Lubow (Space Telescope Science Institute)

Topic: Protoplanetary disks

Orbital Dynamics and Stability of Circumbinary Planets

We investigate the dynamics of planets orbiting around eccentric binaries for varying binary eccentricity, binary mass fraction and planet mass. For sufficiently high initial inclination, the planet orbit precesses about the binary eccentricity vector rather than the binary angular momentum vector. We find that high mass planets are more likely to precess about the binary eccentricity vector than low mass planets. Our results have implications for three-body systems as well as circumbinary discs.

Patrick Cronin-Coltsmann (University of Warwick)

Grant Kennedy (University of Warwick), Cathie Clarke (University of Cambridge), Gaspard Duchêne (University of California Berkeley), Jane Greaves (Cardiff University), Wayne Holland (Science and Technology Facilities Council), Paul Kalas (University of California Berkeley), Samantha Lawler (NRC-Herzberg Astronomy and Astrophysics), Jean-François Lestrade (Observatoire de Paris), Brenda Matthews (NRC-Herzberg Astronomy and Astrophysics), Andrew Shannon (Pennsylvania State University), Mark Wyatt (University of Cambridge)

Topic: Debris Disks

ALMA Observations of the Fomalhaut C Debris Disk its Insights on the History of the Fomalhaut System

We report the first ALMA observations at 0.86 mm of the debris disk around Fomalhaut C, an M4V star in the 440 Myr old Fomalhaut triple star system (Mamajek et al 2013). The star has been previously observed in Hubble Space Telescope scattered light and with the Herschel Space Observatory (Kennedy et al. 2014); the HST observations seemed to display a warped disk structure and the Herschel observations predicted an ALMA measured flux of 1-4 mJy. The new ALMA observations unveil a moderately inclined planetesimal disk at 26.5 ± 0.5 au with a measured flux of 0.8 ± 0.1 mJy. The orbital parameters of the disk and follow up HST observations indicate that the original HST structure was likely an artefact, however a modest 2.4 σ offset of 2 au is measured between the disk model centre and the predicted GAIA DR2 location. This provides some credence to the theory that Fomalhaut A and C were once closer in the dynamical history of the system before they settled in their current unusually large separation (Shannon et al 2014). In such a scenario the interactions between the two stars could have resulted in their disk's mutual offsets and influenced their uncharacteristic brightnesses, precluding the need to invoke unseen planets.

Kennedy GM, Wyatt MC, Kalas P et al. 2014. MNRASL. 438. 96
Mamajek E, Bartlett JL, Seifhart A et al. 2013. AJ. 146. 154
Shannon A, Clarke C and Wyatt M. 2014. MNRAS 442. 142

Katie Crotts (University of Victoria)

Brenda Matthews (National Research Council)

Topic: Debris Disks

A Deep Polarimetric Study of the Asymmetrical Debris Disk HD 106906

HD 106906 is a young, possible binary star system, located in the Lower Centaurus Crux (LCC) group. This system is unique among known systems, in that it contains an asymmetrical debris disk, as well as an ejected 11 Mjup planet companion, HD 106906 b, at a separation of 650 AU. The debris disk is nearly edge on, and extends roughly from 50 AU to >500 AU, where previous polarimetric studies with the Hubble Space Telescope have shown the outer regions to have high asymmetry. Deeper data have been taken with the Gemini Planet Imager (GPI), which we have extracted from the GPI Data Reduction Pipeline and will be using to perform a deep polarimetric study of HD 106906's asymmetrical disk. The data were taken in the H-band, where the filter throughput peaks at 1.647μm, and spans ~1.5-1.8μm at >= 50% throughput. Polarimetry is important in the study of debris disks, as it helps us constrain their dust grain characteristics, as well as allowing us to obtain high-contrast images. This in turn, grants us the ability to effectively analyze disk morphology, which is crucial in aiding our understanding of disk evolution and planet formation.

Daniel Cummins (Imperial College London)

James Owen (Imperial College London)

Topic: Protoplanetary Disks

Spiral Arms in the HD 142527 Outer Disc

High-resolution images of protoplanetary discs have revealed many unexpected substructures, challenging our understanding of these systems. One such highly structured disc is that surrounding HD 142527, where a large cavity separates an outer and highly inclined inner disc. The outer disc has been observed to contain spiral features, as well as two intensity nulls in scattered light images. The intensity nulls are well explained by a mutual inclination of 70 degrees between the inner and the outer disc. Here we study the addition of warp to the inner disc. Such a warp would be generated by the companion that is observed to orbit between the inner and outer discs. To investigate this scenario, we perform radiative transfer simulations and compare them to the observed spiral arms.

Ian Czekala (UC Berkeley)

Co-Authors: Eugene Chiang, Sean Andrews, Eric Jensen

Topic(s): Protoplanetary Disks, Exoplanets

The Degree of Alignment Between Circumbinary Disks and their Host Binaries

One legacy of the Kepler mission was the discovery of nearly a dozen transiting circumbinary (CB) planets orbiting eclipsing binary stars. Unfortunately, calculations of the CB planet occurrence rate are degenerate with assumptions of how sensitive Kepler was to CB planets inclined relative to their binary orbital plane. Thankfully, ALMA is providing needed context by spatially resolving an ever-growing sample of circumbinary protoplanetary and debris disks. Using a hierarchical Bayesian framework, we find that all disks orbiting short-period ($P < 30$ days) binary stars have low mutual inclinations consistent with the CB planet population, suggesting that a large population of (undetected) misaligned CB planets orbiting binaries with these periods does not exist and that the CB planet occurrence rate is similar to that around single stars. We further extend our analysis to include all known CB disk systems in the literature, which includes many longer period binary stars but often suffers from incomplete stellar orbits and/or unresolved disk observations. Still, there are already several longer period ($P \gtrsim 30$ days) systems for which coplanarity is highly disfavored (including GW Ori, HD 142527, and IRS 43); some systems are even found in polar configurations (HD 98800B and 99 Her)! The pronounced transition between aligned short-period systems and misaligned long-period systems is particularly exciting in the context of recent theorized warping and dissipation mechanisms for CB disks around eccentric binaries, which are expected to drive systems to either coplanar or polar configurations depending on their initial misalignment.

Jiayin Dong (Penn State)

Rebekah Dawson (Penn State), Andrew Shannon (Penn State), Sarah Morrison (Penn State)

Topic: Debris Disks

Characterizing Exoplanet Properties from Their Debris Disks: Accounting for the Dynamical Effects of Unseen Planets

Debris disks features (e.g., warps, offsets, edges and gaps, azimuthal asymmetries, thickened rings, scale heights) have often been recognized as the signposts of planets. Most existing models assume a single planet is sculpting the disk feature, but recent observations of mature planetary systems (e.g., by radial velocity surveys and *Kepler*) have revealed that many planets reside in multi-planet systems. We investigate if/how planet properties inferred from single-planet models are compromised when multiple planets reside in the system. For each disk feature, we build a two-planet model that includes a Planet b with fixed parameters and a Planet c with a full range of possible parameters. We investigate these two-planet systems and summarize the configurations for which assuming a single planet leads to significantly flawed inferences of that planet's properties from the disk feature.

Virginie Faramaz (Jet Propulsion Laboratory, California Institute of Technology)

John Krist (Jet Propulsion Laboratory, California Institute of Technology)
Karl Stapelfeldt (Jet Propulsion Laboratory, California Institute of Technology)
Geoffrey Bryden (Jet Propulsion Laboratory, California Institute of Technology)

Topic: Debris Disks

From Scattered-Light to Millimeter Emission: A Global View of the Gyr-Old System of HD 202628 and Its Eccentric Debris Ring

We present a multi-wavelength observations of the cold eccentric debris ring surrounding the Gyr-old, solar-type star HD 202628 in scattered light with HST/STIS, at far-infrared wavelengths with Herschel/PACS and SPIRE, and at millimeter wavelengths with ALMA. Similar to the debris disk of Fomalhaut, the ring appears much narrower at millimeter wavelengths than at optical wavelengths, while its inner edge is found to be consistent between ALMA and HST data. The offset of the ring centre of symmetry from the star allows us to quantify its eccentricity to be $e=0.09\pm0.02$. This eccentric feature also reveals itself in low resolution Herschel/PACS observations, in the form of a pericenter-glow. Upper limits on the gas mass provided by ALMA data allow us to exclude gas-solid interactions as the reason for the narrowness and eccentricity of the ring, which implies the presence of a distant belt-shaping eccentric perturber in this system. From the combination of the ALMA and the Herschel photometry, we retrieve a disk grain size distribution index of $\sim$-3.5, and therefore exclude in-situ formation of the inferred perturber, for which we provide new dynamical constraints.

Alessia Franchini (University of Nevada, Las Vegas)

Rebecca G. Martin (University of Nevada, Las Vegas)
Stephen H. Lubow (Space Telescope Science Institute)

Topic: Multi-planet systems in binary stars

Multi-Planet Disc Interactions in Binary Systems

Understanding the evolution of multi-planet systems in binary stars is crucial to explaining observed exoplanet orbital properties. In particular, most massive extrasolar planets have significantly eccentric orbits and misalignments of planets very close to their host star are quite common. We examine the evolution of a misaligned multi-planet-disc system around one component of a binary star. We find that planets that open gaps in a tilted disk become misaligned with respect to the disc and to each other. In addition, the planet orbits can become eccentric due to to the Kozai-Lidov effect.

Logan Francis (University of Victoria)

Dr. Nienke van der Marel (NRC - HAA)

Topic: Protoplanetary Disks

Gas Structure and Accretion Flow in the DM Tau Transition Disk Gap

Transition disks - protoplanetary disks with large inner dust gaps - are of great interest in planet formation. The presence of dust depleted gaps in transition disks has been widely attributed to the clearing of material by a giant planet within the gap. Many of the pre-main-sequence stars which host transition disks also show signs of active accretion, suggesting the presence of gas in the inner disk. In previous CO studies of similar transition disks, the depth of the gas gaps appeared to be inconsistent with measured accretion rates. In this study, we aim to use both CO observations and accretion rates to interpret the gas structure of the transition disk DM Tau. ALMA observations of DM Tau have resolved a dust depleted gap bound by inner and outer rings between radii of ~4 and ~20 AU, within which a candidate giant planet has been detected at ~6 AU. DM Tau is known to have an active accretion at a rate of 6x10-9 M⊙ yr-1, suggesting that gas may be present within and actively transported through the gap. I will present results from an analysis of the DM Tau gas structure obtained using the thermochemical modelling code DALI, using ALMA observations of dust and CO isotopologues and taking into account the known accretion rate. These results will explore the viability of the scenario in which accretion through the gap may be mediated by the presence of a giant planet.

Wesley Fraser (NRC Herzberg)

Megan E. Schwamb (Gemini Telescope)
Michele T. Bannister (Queen's University, Belfast)
Michael Marsset (Massachusetts Institute of Technology)
Rosemary E. Pike (Academica Sinica Institute of Astronomy and Astrophysics)
JJ Kavelaars (National Research Council of Canada)
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Matthew J Lehner (Academica Sinica Institute of Astronomy and Astrophysics)
Shiang-Yu Wang (Academica Sinica Institute of Astronomy and Astrophysics)
Audrey Thirouin (Lowell Observatory)
Audrey Delsanti (CNRS Lam)
Nuno Peixinho (University of Coimbra)

The Compositional Structure of the Proto-planetesimal Disk

It is generally accepted that the Solar System underwent a large reorganization after the epoch of formation, which was responsible for the outward spread of the gas-giant planets, and the dispersal of the proto-planetesimal disk. The strongest evidence for this reorganization comes from the dynamical structure of the outer Solar System. Further evidence has recently been presented, including similarities in the size distributions of seemingly unrelated planetesimal populations, and contamination of the outer Solar System planetesimal reservoirs by objects with asteroidal compositions. Compositional surveys have revealed the signatures of the dispersal in the compositional-dynamical structure of the current planetesimal populations. The distribution of the known surface types of Kuiper Belt Objects are now being used to infer the compositional structure of the protoplanetesimal disk itself. We will present the results of the Colours of the Outer Solar System Origins Survey (Col-OSSOS), a brightness limited, optical-NIR photometry survey of Kuiper Belt Objects. We will present what has been inferred about the structure of the protoplanetesimal disk, and the migration of the planets from Col-OSSOS and other survey's results. In summary, the protoplanetesimal disk appears to have a moderately homogenous material distribution, with only three distinct regions between ~18 and 45 AU, that resulted in three surface types. Moreover, the orbital classes on which some unique Kuiper Belt populations are found requires that Neptune have at least one phase of smooth outward migration.

Claire Geneser (Mississippi State University)

Angelle Tanner (Mississippi State University)

Topic: High contrast imaging / Adaptive optics imaging

Evaluating the Significance of Spin-Orbit Misalignment in Hot Jupiter Systems

We have analyzed a set of ten stars with known transiting planets with the intention of discovering additional planets or brown dwarfs at wider separations. The high contrast visible and infrared images were gathered with the use of the Magellan VisAO and Clio instruments. Observed 2014 and 2015, the targets were chosen based on their measured spin-orbit misalignment with respect to their host stars rotation axis. One explanation for the orbit misalignment is the Kozai mechanism, which operates through the exchange of orbital inclination and eccentricity between a planet and a distant massive companion. Follow up measurements of common proper motion with the host star will either confirm or reject the presence of any stellar companion. Final analysis was completed through the use of Vortex Image Processing package (VIP) which utilizes high-contrast image processing algorithms to improve sensitivity to faint companions. Here, we present the details and results of this analysis including whether any of our ten targets have bona fide companions based on common proper motion confirmation.

Namrah Habib (University of Cambridge)

Mark Wyatt (University of Cambridge)

Topic: Science Research

Characterizing the Exozodi Luminosity Function with LBTI

The population of cold Kuiper belts around nearby stars is well characterised from far-IR observations. This model predicts the levels of hot dust that would be expected to migrate in from this cold belt population into the inner regions by P-R drag. While collisions destroy much of the dust before it makes it in (Wyatt 2005), that which does can be at a level that may be detectable by HOSTS (Mennesson et al. 2014). Here we apply the model to the population of nearby stars showing that the model predicts an up-turn in the luminosity function from this dragged in dust component. Such an up-turn is seen in the HOSTS data (Ertel et al. 2018), but at a brightness level 10^{-2} zodi an order of magnitude higher than predicted. This could either indicate that there is an additional source of hot dust (e.g., exocomets or exoasteroid belt) in the currently detected systems, or that our simple model for this process requires revision. In any case, we predict that a large fraction of stars will have exozodi at the 10^{-3} level, which is detectable with HOSTS for the best stars, although this fraction depends on an extrapolation of the population of cold belts from those currently detectable. If exozodi are indeed common at the10^{-3} level, then this may cause problems for exo-Earth imaging.

Antonio Hales (NRAO/ALMA)

Topic: Protoplanetary Disks

Looking Through the Hourglass: Unveiling Episodic Accretion with ALMA

Low-mass protostars appear to require short episodes of enhanced accretion to explain how they gain their final mass while displaying seemingly low luminosities. These 'episodic accretion' events are evidenced in FUor and EXor objects and can last from days to decades. Interestingly, the processes behind these enhanced accretion and concomitant outburst events remain poorly understood. Internal instabilities (thermal, gravitational, magnetorotational) as well as external perturbations by companions have been proposed as possible triggering mechanisms. Connecting inner disk studies to observations of the main mass reservoirs in the outer disk and/or envelope is fundamental to understanding low-mass stellar evolution and planet formation.

I will present our recent ALMA results on targeted and survey studies of FUor and EXor outbursting systems.

Cassandra Hall (University of Leicester)

Ruobing Dong (University of Victoria), Ken Rice (University of Edinburgh), Tim Harries (University of Exeter), Joan Najita (NOAO), Richard Alexander (University of Leicester) Sean Brittain (Clemson University)

Topic: Protoplanetary disks

The Temporal Requirements of Directly Observing Self-Gravitating Spiral Waves in Protoplanetary Discs with ALMA

We investigate how the detectability of signatures of self-gravity in a protoplanetary disc depends on its temporal evolution. We run a one-dimensional model for secular timescales to follow the disc mass as a function of time. We then combine this with three-dimensional global hydrodynamics simulations that employ a hybrid radiative transfer method to approximate realistic heating and cooling. We simulate ALMA continuum observations of these systems, and find that structures induced by the gravitational instability (GI) are readily detectable when the disc-to-star mass ratio (q) is larger than roughly 0.25, and the outer radius is roughly less than 100 au. The high accretion rate generated by gravito-turbulence in such a massive disc drains its mass to below the detection threshold in 10,000 years, or approximately 1 % of the typical disc lifetime. Therefore, discs with spiral arms detected in ALMA dust observations, if generated by self-gravity, must either be still receiving infall to maintain a high q value, or have just emerged from their natal envelope. Detection of substructure in systems with lower q is possible, but would require a specialist integration with the most extended configuration over several days. This disfavours the possibility of GI-caused spiral structure in systems with $q<0.25$ being detected in relatively short integration times, such as those found in the DSHARP ALMA survey (Andrews et al. 2018; Huang et al. 2018). We find no temporal dependence of detectability on dynamical timescales.

Jun Hashimoto (Astrobiology Center in Japan)

Tomoyuki Kudo (Subaru Telescope), Takayuki Muto (Kogakuin University), Hauyu Liu (ASIAA), Ruobing Dong (Victoria University), Yasuhiro Hasegawa (JPL), Takashi Tsukagoshi (NAOJ), Mihoko Konishi (Oita University)

Topic: Protoplanetary Disk

ALMA Long Baseline Observations of the Inner Disk Around DM Tau

We present Atacama Large Millimeter/submillimeter Array (ALMA) observations of the dust continuum emission at 1.3 mm and 12CO J=2-1 line emission of the transitional disk around DM Tau. DM Tau's disk is thought to possess a dust-free inner cavity inside a few au, from the absence of near-infrared excess on its spectral energy distribution (SED). Previous submillimeter observations were, however, unable to detect the cavity; instead, a dust ring about 20 au in radius was seen. The excellent angular resolution achieved in the new ALMA observations, 43 × 31 mas, allows discovery of a 3 au radius inner dust ring, confirming previous SED modeling results. This inner ring is symmetric in continuum emission, but asymmetric in 12CO emission. The known (outer) dust ring at about 20 au is recovered and shows azimuthal asymmetry with a strong-weak side contrast of about 1.3. The gap between these two rings is depleted by a factor of about 40 in dust emission relative to the outer ring. An extended outer dust disk is revealed, separated from the outer ring by another gap. The location of the inner ring is comparable to that of the main asteroid belt in the solar system. As a disk with a "proto-asteroid belt," the DM Tau system offers valuable clues to disk evolution and planet formation in the terrestrial-planet-forming region.

Melissa Hoffman (National Radio Astronomy Observatory)

Amanda Kepley (National Radio Astronomy Observatory)

Topic: Other

Correcting ALMA 12-m Array Data for Missing Short Spacings Using the Green Bank Telescope

The Atacama Large Millimeter/submillimeter Array (ALMA) offers astronomers high resolution and exceptional point source sensitivity via its main array of fifty 12-m antennas that can be configured on baselines as long as 16.2km. These capabilities come at the cost of reduced sensitivity to extended emission and an inability to measure total power. The Atacama Compact Array (ACA) component of ALMA is designed to capture extended emission and measure the total power via an array of eleven 7-m antennas and four 12-m total power antennas. The total power antennas in ACA are designed to measure the total flux from a source; their resolution is comparable to the primary beam of the 12-m array. The 100 m Green Bank Telescope (GBT) offers a complementary way to obtain short-spacing and total power data for ALMA observations for observations within their overlapping sky coverage δ=-40°to δ=+40° and frequency ranges (84GHz to 116GHz). Since the GBT has a diameter ~10 times greater than the ALMA total power antennas, it has more overlap in u-v space with the ALMA 12-m baselines than the total power antennas. These characteristics may provide improved reconstruction of the large-spatial scales in the images. Our goal is to answer two questions: Can we map out a way in CASA to use the GBT in place of the Total Power (TP) array when combining with ALMA interferometric data? How does the flux reconstruction of a GBT+ALMA combination compare to TP+ALMA combination?

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Marshall Perrin (Space Telescope Science Institute)
Bruce Macintosh (Stanford University)
Gaspard Duchêne (University of California, Berkeley)
Maxwell Millar-Blanchaer (Jet Propulsion Laboratory)
Michael P. Fitzgerald (University of California, Los Angeles)
James R. Graham (University of California, Berkeley)
Pauline Arriaga (University of California, Los Angeles)
Sebastian Bruzzone (University of Western Ontario)
Kadin Worthen (Arizona State University)
Kezman Saboi (Arizona State University)
And The GPIES Collaboration

Topic: Debris Disks

First Scattered Light Detections of Four Debris Disks in Scorpius-Centaurus with the Gemini Planet Imager

We present the first spatially resolved scattered light images of four debris disks in the Scorpius-Centaurus OB association based on observations with the Gemini Planet Imager. The four targets are a selection of early-type A and F stars with IR excess emission levels ranging from 4.1x10^(-4)-1.4x10^(-3) LIR/Lstar located in the Upper Centaurus Lupus and Lower Centaurus Crux regions of Sco-Cen. The high contrast imaging was performed in the H-band and included both polarimetry and spectral mode data. The results from this study of four newly resolved debris disks contributes to a larger ongoing survey investigating the frequency and morphology of resolved disks around ~30 Sco-Cen early-type stars with high infrared excesses. Overall goals of the survey include exploring the range of debris disk properties around stars of similar age and formation environment, placing constraints on disk geometric properties and the potential dynamical signatures of planets. The four disks span a spatial range from ~0.”42-0.”85. Of the four targets selected, three have close to edge-on geometry while the other is highly inclined, showing more of a ring structure. One target shows significant asymmetry, possibly indicating the presence of a substellar companion gravitationally interacting with the debris disk.

Xiao Hu (Department of Physics and Astronomy, University of Nevada, Las Vegas)

Lile Wang (Center for Computational Astrophysics, Flatiron Institute)
Satoshi Okuzumi (Department of Earth and Planetary Sciences, Tokyo Institute of Technology)

Topic: Protoplanetary Disks

Global Simulations of HL-Tau with Coupled Non-ideal Magnetohydrodynamics and Consistent Thermochemistry

Recent high resolution observations unveil various ring structures in circumstellar disks. The origin of these rings has been widely investigated through different theoretical assumptions. In this work we perform global magnetohydrodynamcs (MHD) simulations using Athena++, coupled with ray-tracing radiative transfer, consistent thermochemistry, and non-ideal MHD diffusivities. Dust assisted recombination is crucial to Ohmic resistivity and ambipolar diffusion (AD), and these non-ideal MHD effects are known for suppressing MRI, thus varying disk accretion. The rings and gaps in HL Tau disk can be reproduced from dust evolution modelling that includes the sintering effects close to snowlines of major volatiles. We incorporate this dust grain distribution in our MHD simulations to model the HL Tau disk.

Jeff Jennings (Institute of Astronomy, University of Cambridge)

Eric Agol (Astronomy Department, University of Washington)

Topic: Exoplanets

When, How and Why the TTV Mass-Eccentricity Degeneracy Can Bias Recovered Planet Masses

In multi-planet systems near or in mean motion resonance (MMR), the gravitational perturbation between bodies is sufficient to cause a detectable aperiodicity in a transiting planet's signal. These transit timing variations (TTVs) yield a mass estimate on the perturbing body and offer a comparison measurement for minimum planet masses obtained with the radial velocity technique. However masses inferred from TTVs are susceptible to a mass-eccentricity degeneracy that we have found induces a weak but persistent bias toward erroneously low or high planet masses (depending on orbital and observational conditions) recovered in MCMC parameter inversion with semi-analytic simulations. I will present an overview of our findings on the bias' severity, focusing on its sensitivity to physical and observational quantities: its prominence at eccentricities <0.03, high sensitivity (including sign) to distance from MMR, and observational negation only at signal-to-noise >30 (<10 s noise on 5 minute TTVs) or sampling over >2 TTV super periods. To motivate efforts to correct for the bias, I will then summarise our analysis of its analytic origin. Concluding with a demonstration of the bias' potential effect on recovered masses in real systems, I will briefly discuss implications for the TTV/RV mass discrepancy and for TTV analysis in the context of both current and near future (low noise, long baseline) transit surveys.

Michelle Kunimoto (University of British Columbia)

Jaymie Matthews (University of British Columbia)

Topic: Exoplanets

An Independent Search of *Kepler* Data: New Planet Candidates and Occurrence Rates

Ultraprecise photometry from space satellites like NASA's *Kepler* mission has led to a revolution in the discovery and characterization of planets beyond the Solar System. Even in the existing datasets, there are important detections and correlations yet to be made. This work aims to make contributions on both fronts. First, we detail our independent search through the light curves of all ~200,000 *Kepler* target stars for new planets, including those in the low-S/N regime not previously searched by the *Kepler* team. We have found that up to 100 candidates have been missed by previous searches, including potentially rocky planets in the Habitable Zones of their stars. Second, we describe steps towards deriving exoplanet occurrence rates from our final planet catalogue using forward modelling and Approximate Bayesian Computing. Of particular interest is the frequency of habitable Earth-like exoplanets, also known as eta-Earth. There is no consensus for the value of eta-Earth in the astronomical community as of yet, making a new and independent estimate based on a low-S/N search of *Kepler* data an important addition.

Nicolás T. Kurtovic (Universidad de Chile)

DSHARP collaboration (Andrews et al. 2018)
L. Pérez, M. Benisty, Z. Zhu, S. Zhang, J. Huang, S. Andrews, C.P. Dullemond, A. Isella, X. Bai, J.M. Carpenter, V.V. Guzman, L. Ricci, D.J. Wilner.

Topic: Protoplanetary Disks

Dust and Gas Substructures in Disks Around Multiple Star Systems

As part of the "Disk Substructures at High Angular Resolution Project" (DSHARP) collaboration, we observed the protoplanetary disks of the young multiple star systems AS 205 and HT Lup, with ALMA at high angular resolution, and spatially resolve physical scales of ~5 au.

In the continuum emission, we find two symmetric spiral arms in the disk around AS 205 N, with a pitch angle of 14°, while the southern component AS 205 S, itself a spectroscopic binary, is surrounded by a compact inner disk and a bright ring at a radius of 34 au. The 12CO line exhibits clear signatures of tidal interactions, with spiral arms, extended arc-like emission, and high velocity gas, possible evidence of a recent close encounter between the disks.

In the HT Lup system, we detected and resolved continuum emission from three components. The primary disk, HT Lup A, also shows two symmetric spiral arms with a pitch angle of 4°, while the disks around HT Lup B and C, located at 25 and 434 au in projected separation from HT Lup A, are barely resolved with ~5 and ~10au in diameter, respectively. The gas kinematics for the closest pair indicates a different sense of rotation for each disk, which could be explained by either a counter rotation of the two disks in different, close to parallel, planes, or by a projection effect of these disks with a close to 90° misalignment between them.

HT Lup and AS 205 contains some of the smaller disks of the DSHARP sample, besides, disks with spirals in these systems do not present rings structures, which could be a hint about the implications of binaries interaction in planet populations.

MatthewLehner (ASIAA)

Shiang-Yu Wang (ASIAA), Mauricio Reyes-Ruiz (UNAM), Zhi-Wei Zhang (ASIAA).
Liliana Figueroa (UNAM), Chung-Kai Huang (ASIAA), Wei-Ling Yen (ASIAA), Charles Alcock (CfA), Fernando Alvarez Santana (UNAM), Joel Castro-Chacón (UNAM), Wen-Ping Chen (NCU), You-Hua Chu (ASIAA), Kem H. Cook (ASIAA), John C. Geary (CfA), Benjamín Hernández (UNAM), Jennifer Karr (ASIAA), Jj. Kavelaars (UVic), Timothy Norton (CfA), and Andrew Szentgyorgyi (CfA)

Topic: Solar System

The Transneptunian Auomated Occultation Survey

The Transneptunian Automated Occultation Survey (TAOS II) will aim to the Kuiper Belt and beyond. Such events are very rare ($<10^{-3}$ events per star per year) and short in duration (~200 ms), so many stars must be monitored at a high readout cadence in order to detect events. TAOS II will operate three 1.3 meter telescopes at the Observatorio Astronómico Nacional at San Pedro Mártir in Baja California, México. With a 2.3 deg.^{2} field of view and high speed cameras comprising CMOS imagers, the survey will monitor 10,000 stars simultaneously with all three telescopes at a readout cadence of 20 Hz. Construction of the site began in the fall of 2013, and the survey will begin by the end of 2019. This poster describes the observing system, the status of the survey infrastructure, and the expected survey sensitivity.

Jarron Leisenring (University of Arizona)

Marcia Rieke (University of Arizona)
Chas Beichman (CalTech)

Topic: Exoplanets

NIRCam GTO Observations of Disks and Planets

JWST NIRCam's coronagraph offers a dramatic increase in sensitivity at wavelengths between 3 and 5 microns where young planet atmospheres and warm circumplanetary material are especially bright. While extreme adaptive optics on large ground-based telescopes provide exceptional contrast at close inner working angles, NIRCam will provide high-precision photometry for known planets as well as unprecedented sensitivity to search for companions with masses below that of Saturn. NIRCam coronagraphy further enables observations of debris disks in scattered light to search for the presence of ices and tholins while also hunting for planets that may influence the disk structure. The NIRCam science team's GTO program consists of an extensive set of observations to characterize known young planets with 1-5 M_{Jup}. Coupled with a complementary MIRI program at longer wavelengths, the combined datasets will provide information including the exoplanet's effective temperature, total luminosity, atmospheric properties, and estimate of initial entropy. The NIRCam program further includes deep searches for lower mass planets orbiting nearby M Dwarfs and debris disk systems. We will discuss details of science drivers, simulations of the observations, and expected results of this program.

Hui Li (Los Alamos National Laboratory)

Yaping Li, Shengtai Li (LANL), Doug Lin (UCSC)

Topic: Protoplanetary Disks

Interaction between Disks and Planets on Eccentric Orbits – Implications for Dust Rings, Gaps, and Spiral Features

We report new results on studying the interaction between dusty protoplanetary disks and planets on eccentric orbits. We find that planet's orbits will eventually become circularized due to the planet-disk interaction, and during this process, the dust distribution will be affected depending on the timescale and final location of circularization. This scenario can significantly affect the global dust evolution, particularly in keeping dust mass at large disk radius. It also leads to the emergence of dust rings and gaps, and provides constraints on inferring the planet masses associated with such structures. Furthermore, depending on the disk evolution stages and disk masses, certain spiral features can be excited via such interactions. By comparing with observations, we discuss the constraints on disk and dust properties (mass, viscosity, etc.) and the likely planet masses.

Jian Li (Nanjing University, ljian@nju.edu.cn)

Li-Yong Zhou (Nanjing University)
Yi-Sui Sun (Nanjing University)

Topic: Science Research

The Dynamics of the *High-Inclination* Kuiper Belt Objects

The dynamical stability and evolution of the Kuiper belt objects (KBOs) with high inclinations are systematically explored. By making use of a semi-analytical model based on the simplified disturbing function, we have provided new insights into the dynamics of the (2:3, 1:2, 4:7 and other high order) mean motion resonances and secular resonances, the peculiar orbital distribution of currently KBOs. Combining with numerical simulations, we further reconcile the origin/evolution of these objects with our current understanding of the formation of the outer Solar system.

Min-Kai Lin, Jhih-Wei Chen (ASIAA, NTU)

Topic: Protoplanetary Disks

Dust-Rich Disk-Planet Interaction

After their formation, young protoplanets continue to interact with their parent disk. Disk-planet interaction plays a major role in the evolution of planetary systems from both theoretical and observational perspectives. While much of the recent interest in disk-planet interact is the formation of sub-structures such as dusty rings, gaps, and asymmetries; how the planet responds to the dusty disk is less well-explored. In this work we perform numerical simulations of low mass planets embedded in dusty disks with focus on disk-planet torques. We apply a novel hydrodynamic framework for simulating dusty gas. We consider the dust-rich limit, applicable to the settled dust layers in the disk midplane, or disks subject to mass loss through winds. We find with increasing dust-loading, disk-planet torques become oscillatory, unlike the dust-poor (pure gas) case where torques saturate to a constant value. We show this is due to the generation of vorticity resulting from finite dust-gas coupling. In some cases vortex instabilities develop near the planet. Implications for planet migration are discussed.

Min-Kai Lin (ASIAA)

Topic: Protoplanetary isksD

Dust Settling in Turbulent Protoplanetary Disks

Recent observations of protoplanetary disks frequently reveal well-defined dust rings and gaps. These features are often interpreted as signs of ongoing planet formation. In addition, their sharpness indicate that dust has settled to the disk midplane. Theoretical considerations, on the other hand, suggest that protoplanetary disks should be subject to a plethora of fluid instabilities that drive turbulence, which would stir up dust particles. How can dust settle in spite of turbulent stirring? We perform numerical simulations of dusty protoplanetary disks to settle this conundrum. We focus on large radii, accessible by ALMA, where the disk can develop a `vertical shear instability' characterized by large-scale vertical motions, which tends to loft small particles. However, we find that sufficient dust-loading can actively stabilize the disk and permit dust to settle. This means that dust settling is also a function of the solid abundance: more dust settles better. Thus, observations of thin dust layers may provide an indirect constraint on the local solid abundance. Our models also suggest that the dust rings should be thinner than dust gaps.

Joshua Bennett Lovell (University of Cambridge)

Sebastian Marino (Max-Planck-Institut für Astronomie, Heidelberg), Mark Wyatt (University of Cambridge), Meredith MacGregor (Carnegie Institution), Karl Stapelfeldt (California Institute of Technology).

Topic: Debris Disks

High Resolution Imaging of the q1 Eri Planetary System

High resolution Band 7 ALMA continuum imaging of the nearby (17.4pc) circumstellar debris disk orbiting the >1Gyr-old F9 main-sequence star, q1 Eri, has revealed in unparalleled detail the structure of the system's main dust belt, extending over a broad width of 45-130au. In conjunction with the Band 7 imaging, archival Band 6 ALMA and Hubble Space Telescope data have been combined to provide a multi-wavelength view of the disk. Observational diagnostics applied to these images have revealed an asymmetry in the brightness distribution and a radial offset from the star. q1 Eri is known to have a planet, an exo-Jupiter (q1 Eri b) orbiting with a small eccentricity (~10%) at 2.1au. At such a radius, asymmetric features in the disk cannot be explained by secular interactions with this planet due to the low forced eccentricity these parameters provide in comparison to the observed disk features. Modelling is presented to constrain the properties of a potential second planet that may explain these radial and brightness asymmetries as a result of an imposed forced eccentricity, in addition to the known planet. A deep search for Carbon Monoxide gas (J=3-2) has also been performed with spatial and spectral filtering, with no significant detection being made at a radial velocity consistent with the stellar recession velocity. This has provided a preliminary constraint on the CO gas mass present that is below ALMA's Band 7 detection threshold for this line transition, consistent with predictions for this planetary system.

Sebastian Marino (Max Planck Institute for Astronomy, Heidelberg, Germany)

Topic: Debris Disks

Evolution of Exocometary Gaseous Discs Including Collisional Evolution

Planetary systems are not only composed of planets but also by solids in a wide size distribution from um-sized dust up to km-sized bodies. Thanks to infrared observations we know today that about 20% of nearby stars exhibit a significant amount of dust at tens of au, which originate from collisions of larger km-sized asteroids/comets. These planetesimals are usually confined into belts analogous to the Kuiper belt and provide a unique window to study exoplanetary systems. But not only dust is found, molecular gas is also found around some of these systems, whose origin can hardly be primordial (i.e. protoplanetary disc leftovers).

It was only recently that a comprehensive picture for the presence of gas in these systems with bright debris discs arose. As planetesimals collisions release dust, these also release volatiles, such as CO, that are trapped within ices and refractories. While gas is released and exposed to UV radiation from the star and interstellar medium, molecules photodissociate creating an atomic accretion disc that viscously evolves. Current models, however, only consider a constant input rate of gas in the system, while in reality, exo-Kuiper belts grind down in time due to the same collisions, and therefore the rate at which gas is released has decreased with time.

I have investigated using simulations how the evolution of an exocometary gaseous disc is affected when the rate at which gas is released decreases with time due to the collisional grinding of planetesimals. I have found that the observed levels of CO, C, O, etc. can strongly depend on how the system has evolved to its current state, i.e. if the planetesimal disc was much more massive in the past or rather started with a total mass similar to today's mass. This is dramatically different to dust observations, which typically leave unconstrained the current and initial total mass in the disc, as the system quickly losses memory from its initial state. The model presented here can also be used to make population studies and constrain the diversity of initial conditions in debris disc evolution. Finally, the awakening of a second generation gaseous disc could be a potential source of volatiles for terrestrial planets closer in.

Christian Marois (National Research Council of Canada)

Topic: Exoplanets

TMT PSI/MICHI: Imaging and Characterization of Rocky Earth-size Habitable Zone Planets in the Solar Neighborhood

TMT, with an impressive ~200x gain (D^4) in integration time compare to current generation of 8-m telescopes, as well as delivering ~4x higher resolution, will open-up, first the first time, the ability to directly image and characterize Earth-size planets around several nearby stars. Starting with some basic assumptions, I will summarize the expected sensitivity performances, and will discuss the requirements necessary to achieve a 5-sigma detection of an Earth-analog in nearby systems. I will show some early simulations of a 10 microns TMT thermal imager, as well as the instrument overall concept. Finally, I will review the various challenges that will need to be resolved to enable this breakthrough science case.

Jonathan P. Marshall (ASIAA)

Nicole Pawellek (MPIA Heidelberg)
Grant Kennedy (University of Warwick)
Peter Scicluna (ASIAA)
Alexander Krivov (Friedrich-Schiller Universität, Jena)

Topic: Debris Discs

Inferring the Size Scales of Planetary Systems Using Resolved Debris Discs

Circumstellar debris discs are tenuous remnant rings of icy and rocky material left over from planet(esimal) formation processes around their host stars. Possible relationships between stellar luminosity and disc parameters have been examined. Based on analysis of a sample of 39 spatially resolved debris discs at infrared wavelengths by Herschel, a trend between stellar luminosities ($L_{\rm star}$) and the ratio of the discs' resolved radii to blackbody radii ($R_{\rm disc}/R_{\rm bb}$) was noted.

We have examined a larger sample of resolved debris discs from archival far-infrared Herschel observations in order to determine the fidelity of that trend. We further examine whether the inferred extents of these discs are consistent with self-stirring models or may be indicative of dynamical perturbation by a planetary companion. Disc radii were determined by fitting the source brightness profiles with simple annular disc models convolved with a PSF. We obtain good agreement between the resolved extent of debris discs as measured at millimetre wavelengths and the estimates based on $L_{\rm star}$ and $R_{\rm disc}/R_{\rm bb}$ at far-infrared wavelengths, suggesting that the measured trend is a fair, albeit imperfect, predictor of actual disc extent. Furthermore, we identify several systems with radii larger than expected given the ages of their host stars, based on comparison with simple stirring models.

Obtaining a reliable indirect measure of the radii of debris discs is of paramount importance to facilitate interpretation of their architectures, possible stirring, and formation mechanisms, from unresolved data e.g. such as is expected from Spica. Such data can be combined with the results of exoplanet detections from e.g. TESS and Gaia to identify the importance of disc-planet interactions to the evolutionary histories of these planetary systems.

Elisabeth Matthews (MIT)

Sasha Hinkley (University of Exeter)
Arthur Vigan (Laboratoire d'Astrophysique de Marseille)
Grant Kennedy (Univeristy of Warwick)
Tiffany Meshkat (California Institute of Technology)
Dimitri Mawet (California Institute of Technology)
Farisa Morales (JPL)
Andrew Shannon (Penn State)
Karl Stapelfeldt (JPL)

Topic: Debris Disks, Exoplanets

Searching for Giant Exoplanets in Systems with Sculpted Debris Dust

Circumstellar debris dust is believed to be associated with extrasolar planets, and there is some observational evidence suggesting a link between giant, wide separation planets and debris dust (Meshkat et al., 2017). Of particular interest are those systems where the debris dust is sculpted, i.e. where there is some dynamical hint at the presence of these giant planets - for example, sharp edges to debris rings, or two-belt systems where the rings of dust enclose a gap (see e.g. Apai 2008). If we assume that the gap in such systems is formed by once or more giant planets, it is possible to place both upper and lower limits on the masses of these planets by combining direct imaging and dynamical arguments. In this talk I will describe two direct imaging surveys where we search for giant, wide-separation planets in highly dusty systems, and in dusty systems that show evidence of sculpting into multiple debris belts. In particular, I will describe how we can use the dust configuration to tightly constrain the parameter space, and I will additionally present our scattered light images of the HD129590 debris disk.

Johan Mazoyer (Jet Propulsion Laboratory, Pasadena, CA)

Christine Chen (STScI, Baltimore, MD)
Charles Poteet (STScI, Baltimore, MD)
Gaspard Duchene (UC Berkeley CA)
Pauline Arriaga (UCLA, CA)
Max Millar-Blanchaer (JPL, Pasadena, CA)
& the GPI LLP collaboration

Topic: Debris Disks

The Surprising Scattering Properties of the HR 4796 A Debris Disk

HR 4796 A is a close-by (72 AU) young A0 star which harbors a debris disk first imaged in scattered light by Schneider et al. (1999). Its narrow and sharply carved belt at 80 AU quickly made it a very popular target for all imaging instruments from the visible to the far IR since then, constraining further its geometrical parameters and spatial extension (Schneider et al. 2009, Thalmann et al. 2011, Rodigas et al. 2015, Perrin et al. 2015, Milli et al. 2015 and 2017, Schneider et al. 2018).

Measurements of scattered light phase functions have long been used as a powerful tool to measure dust grain properties of comets and asteroids in the solar system (Kolokolova et al., 2004). The total intensity, polarized intensity, and color of the scattered light have been used to effectively constrain particle shape, size, composition and porosity. For comets, scattered light findings have been confirmed by spacecraft in-situ measurements. For exosolar debris disks, in-situ measurements are not possible; therefore, high-contrast imaging observations at visible and near-IR wavelengths are needed to infer the dust properties and have been extracted for only a handful of disks so far. The inclination (76°) and projected distance (major axis of 1") of the HR 4796 A disk provide an opportunity to measure the scattering properties of debris dust over a large range of scattering angles (from 16° to 164°). However, in total intensity, the extraction of these observables is complicated by the PSF subtraction techniques applied to coronagraphic images (e.g. angular differential imaging), whose effects have to be carefully corrected.

We have obtained observations in the J-, H-, K1- and K2-bands of the debris disk around HR 4796 A with the Gemini Planet Imager. These observations confirmed the scattering phase function recently extracted from the SPHERE data (Milli et al., 2017). This scattering phase function (SPF) is different from ones not only measured on the limited sample of debris disks but also on various dust populations in the solar system, as it features an extremely forward scattering curve, a dip at scattering angles from 30° to 70° (the SPF minimum is usually around a 90°), and an increase in intensity at high scattering angles. We use a radiative transfer code to constrain the dust properties for this object.

Ryan Miranda (Institute for Advanced Study)

Roman Rafikov (DAMTP Cambridge; Institute for Advanced Study)

Topic: Protoplanetary disks

Multiple Spiral Arms in Protoplanetary Disks

Recent observations of protoplanetary disks, as well as simulations of planet-disk interaction, have suggested that a single embedded planet may excite multiple spiral arms in a disk, in contrast to previous expectations based on linear theory in which a single spiral arm is formed. The nonlinear evolution of the multiple spirals has been linked to the formation of the multiple gaps and rings seen in many disks. We investigate the formation of multiple spirals in the context of linear perturbation theory, solving for the global two-dimensional response of a disk to an orbiting planet. A strong secondary spiral and several weaker spirals are always formed interior to the orbit of the planet. We show that this is a generic outcome of wave propagation in disks, resulting from the complex interference of different azimuthal harmonics of the perturbation. We compute the torque density distribution characterizing the planet-disk interaction, providing a new formula for its profile, and describe how its behavior at large distances from the planet is modified by the details of the spiral structure. Combining linear theory and numerical simulations, we examine the process by which multiple spirals sculpt gaps and rings in the disk. We show that the equation of state of the disk plays a critical role in this process, due to its effect on linear wave propagation. These results have important implications for understanding the formation of spirals, rings, and gaps in protoplanetary disks.

Arielle Moullet (SOFIA / USRA)

William Reach (SOFIA / USRA)

Topic: Solar System

Solar System Science with the Stratospheric Observatory For Infrared Astronomy

Now in its seventh cycle of observations, the Stratospheric Observatory for Infrared Astronomy (SOFIA) and its wide suite of instruments has continued to offer a unique access to the far-IR sky in the 4-600 microns range. SOFIA observations of Solar System bodies have included varied topics such as chemical studies of terrestrial planets atmospheres, moons' exospheres and mineral characterization of asteroids. Thanks to its positioning flexibility, SOFIA has also been instrumental in occultations observation campaigns of Triton, Titan and Kuiper-Belt objects. This poster highlights some of the latest SOFIA Solar System results and new observational opportunities in the context of its latest instrumental developments.

Marco A. Muñoz-Gutiérrez (Academia Sinica Institute of Astronomy and Astrophysics)

Antonio Peimbert (Instituto de Astronomía, UNAM), Bárbara Pichardo (Instituto de Astronomía, UNAM), Matthew Lehner (ASIAA) and Shiang-Yu Wang (ASIAA)

Topic: Solar System

The Contribution of Dwarf Planets to the Origin of Jupiter Family Comets

In this work we explore the long-term dynamical evolution of a bias-free orbital representation of the Kuiper belt, the so-called L7 synthetic model from CFEPS, under the gravitational influence of the sun and the four giant planets, as well as of the 34 largest known TNOs, those with visual absolute magnitude $H_V < 4$, listed at the Minor Planet Center as of February 2018, among which are the four objects currently classified as dwarf planets by the IAU (Pluto, Eris, Haumea, and Makemake); however, in this work we indistinctively call Dwarf Planets (DPs) to all the objects in our 34 members set. Over 1 Gyr time-scales, we analyzed the secular influence of the DPs over Kuiper belt particles and their contribution to the injection rate of new visible Jupiter Family Comets (JFCs), as they make their way from the Scattering, Resonant, and Classical populations to the inner Solar System. We found that DPs effectively increase the number of new visible JFCs originating from the Classical and Resonant populations in almost 20%, when compared with the number of comets produced by the giant planets alone. For the Scattering population the increment is marginal but noticeable. Given the rate of escapes from the Kuiper belt enhanced by DPs, 20% less objects in the Classical and Resonant populations are required to supply the number of JFCs currently observed. Considering recent estimates of the injection rate of new comets required to maintain the population of JFCs in steady state, the maximum numbers of ~1 to ~10 km sized objects required to supply the 100% of new JFCs are $\sim 5.9 \times 10^7$, $\sim 1.0 \times 10^8$, and $\sim 2.9 \times 10^8$ for the Scattering, Resonant, and Classical populations, respectively. By comparing with the number of objects in the same size range expected to be present on each of these populations from recent cratering records predictions on the surface of 2014 MU_{69}, we provide some estimates of the fractional contribution of each population to new visible JFCs. Additionally, we found that the Plutinos are the most important source of comets originally coming from a resonant configuration, where the presence of Pluto and the large plutinos Orcus, 2003 AZ_{84}, and Ixion, are important in increasing the number of unstable 3:2 resonators. On the other hand, the twotinos and the populations in the 5:3 and 5:2 mean motion resonances with Neptune all supply a comparable amount of new visible JFCs.

Rebecca Nealon (University of Leicester)

Christophe Pinte (Monash University)
Richard Alexander (University of Leicester)
Giovanni Dipierro (University of Leicester)
Daniel Mentiplay (Monash University)

Topic: Protoplanetary discs

Does TW Hya Host a Misaligned Planet?

Recent observations of the bright, almost face-on protoplanterary disc TW Hya have identified a dynamic azimuthal brightness variation in the outer disc. This feature is best explained as the shadow cast from an inner disc that has a different orientation to the outer disc – i.e. there is some relative misalignment. In this model, the motion of the inner disc is governed by a planet whose orbit is misaligned to the mid-plane of the outer disc. Here we test this hypothesis using high resolution three-dimensional simulations and synthetic scattered light images. Our simulations show that indeed, a misaligned planet can generate the disc structure invoked from observations. The scattered light images from these simulations indicate that the misaligned planet results in two different mechanisms that cause brightness variations in the outer disc – either of which may be considered as observational signatures that are strongly suggestive of a misaligned companion. Finally, we apply our model to TW Hya, inferring the properties of the planet that would be required in order to match the existing observations.

Tomohiro Ono (Princeton University / Osaka University)

Topic: Protoplanetary disks

Properties of Vortices Formed by the Rossby Wave Instability

ALMA continuum observations have revealed protoplanetary disks with crescent structures. A formation theory of those structures suggests the presence of gas vortices, which can trap dust particles due to gas drag. The Rossby wave instability (RWI) is a hydrodynamic instability and forms gas vortices when a disk has a rapid radial variation. As far as the observations show, all the crescent structures are accompanied by ring-like structures or inner holes. Therefore, the RWI is one of the promising mechanisms for explaining the crescent structures. We investigate vortices formed by the RWI with numerical simulations using the Athena++ code (Ono et al. 2018). We show the properties of the vortices and report some empirical relations between those properties and the initial conditions. We also discuss density waves induced by the vortices. Our studies are useful for understanding planet formation as well as the origin of the observed crescent structures in protoplanetary disks.

James Owen (Imperial College London)

Topic: Protoplanetary discs

Generating Large Mis-alignments in Protoplanetary Discs

Recent high-resolution images, both from scattered light and ALMA have revealed that protoplanetary discs can have large misalignments, in extreme cases up to 70 degrees. Many of these misalignments are present in transition discs, where an inner disc and outer disc separated by a large gap are misaligned. HD 142527 is the prime example and a low-mass stellar companion orbits in the gap. In this talk, I will present a mechanism for generating the misalignments in this system, through a secular precession resonance. When the companion's orbit and inner disc's orbital plane are precessing at the same rate large misalignments will be generated. I will argue that disc evolution and companion migration can lead to the system evolving to the point where this resonance can occur. I will discuss the implications of this mechanism, both regarding its observable consequences and the system's long-term evolution.

Jinghan (Jane) Peng (University of Victoria)

JJ Kavelaars (University of Victoria; NRC-Herzberg)

Topic: Kuiper Belt

Phase Dependent Variation in the Reflectivity of Kuiper Belt Object 2002MS4

We are measuring the phase dependent variation in the reflectivity of Kuiper belt object 2002 MS4. Our goal is to reveal properties of the surface 2002 MS4 by optimizing physical models to the observed phase variability. Determination of non-degenerate physical parameters from phase observations requires observing over a large range of phase angles, which are normally not accessible for KBOs. 2002 MS4, however, is one of about ten TNOs that have or will be observed at a variety of large phase angles using the New Horizons spacecraft. New Horizons does not provide small phase observations, which must be obtained from the grounds. My project goal is to provide those low-phase angle observations for 2002 MS4, allowing a secure the measure of the surface characteristics of this TNO.

My observations consist of images of 2002 MS4 from multiple observatories including CFHT, CTIO-4m, and ESO-VLT. For some of these data sets, the target object of the specific observation might not have been 2002 MS4. These data were found thanks to the powerful Solar System Object Image Search engine of the Canadian Astronomy Data Centre.

Each of these ground based images is first carefully calibrated to the Gaia astrometric reference system, to allow the exact celestial coordinate of the target to be used to confirm the detection of 2002 MS4 in the image. I then determine an in-situ photometric zero-point via comparison of the flux of stars in the image to PanStarrs (PS1) public data. Using these re-calibrated observations, a phase curve can be constructed using the flux measurements and calculation of observation phase angle.

I will report on our progress, to-date, in obtaining the required group based data. I will also describe future work that will be needed before we obtain a complete phase curve for this target.

Ralph E. Pudritz (McMaster University)

Alex Cridland (Leiden Observatory) and Matt Alessi (McMaster University).

Topic: Protoplanetary Disks

The Physics of Planet Traps with Applications to HL Tau

The origin of rings and gaps in protoplanetary disks is one of the great challenges for the theory of planet formation. The ALMA revolution has revealed that these features are found in all well resolved disk systems studied so far. Their origin has been variously ascribed to opacity transitions, gap opening by planets, MHD effects, and the damping of spiral waves induced by just a few planets. No systematic trends have been identified in these systems. We have developed a physical theory of planet traps in evolving protostellar disks based on the physics of opacity transitions and numerical simulations of chemically evolving disks. We apply this work to show that low mass planetary cores can be trapped at water and CO_2 ice lines, and other traps in HL Tau's disk. We find that a 5 Jovian mass planet and smaller Earth mass planets can form within 800,000 yrs in HL Tau as a consequence of trapping. We then address the question of the origin of the observed gaps in the disk of HL Tau.

Ian Rabago and Zhaohuan Zhu (University of Nevada Las Vegas)

Topic: Protoplanetary Disks

Grid-Based Simulations of Tilted Circumbinary Disks

ALMA observations have revealed protoplanetary disks that are not axisymmetric in nature. There are several processes that can lead to this configuration, such as misalignment of the disk and star angular momentum vectors, perturbations from a passing star, or repeated effects from a binary star system inside the disk. In the last case, these circumbinary disks can warp over time and, depending on the inclination of the disk to the binary orbital plane, will eventually align its angular momentum vector with or perpendicular to that of the binary. Motivated by recent observations of polar-aligned disks around binary star systems [i.e. HD 98800], we simulate circumbinary disks of gas using the grid-based code Athena++. The disk is initialized with some inclination with respect to the binary orbit. We test a variety of initial inclinations and study their evolution over time, examining the results for the disk final alignment and possible disk warping.

Enrico Ragusa (University of Leicester)

Topic: Protoplanetary disks

Non-Axisymmetric Features in Protoplanetary Disks: Vortices or Not Vortices? The Quest Continues

In recent years, the observation of a large variety of structures in protoplanetary discs (gaps and rings, cavities, spirals and other non-axisymmetric features) has challenged our understanding of the physical processes involved in the formation and evolution of these systems. The discovery of horseshoe/crescent shaped features in a number of transition discs (i.e., those with a central cavity) has proved particularly difficult to explain. The most commonly invoked scenario is the Rossby Wave Instability (RWI), where an embedded planet produces a strong vortensity gradient which triggers the formation of a vortex, which in turn produces an overdense, non-axisymmetric feature in the disc. However, this mechanism only forms vortices effectively when the disc viscosity is very low, which raises questions about its viability. A second possible scenario involves the presence of a more massive companion (i.e., a brown dwarf or low-mass star) creating tidal streams that shock at the other side of the cavity edge. This mechanism does not require such low disc viscosities, but sufficiently massive companions may not always be present.

In this talk, I will review the mechanisms proposed in the literature for the formation of these non-axisymmetric structures and then focus on our recent results in the massive companion scenario. In particular, I will discuss our efforts in modelling the physical conditions under which this mechanism is effective, and its consistency with observations. I will first discuss how the physical properties of the tidal streams depend on the disc parameters, using 3D SPH simulations to explore a large parameter space. I will then review the detection (or not) of sub-stellar companions in these systems, and the implications of these results.

Bin Ren (The Johns Hopkins University)

Topic: Debris Disks

Exo–Kuiper Belt and Extended Halo around HD 191089 in Scattered Light

We have obtained *Hubble Space Telescope* visible STIS and infrared NICMOS, and *Gemini*/GPI *H*-band scattered light observations of the HD 191089 debris disk. We identify two spatial components: (1) a ring resembling Kuiper Belt in radial extent (FWHM: ~21 au, centered at ~44 au), and (2) an outer halo extending to ~640 au. We compare the STIS and NICMOS observations, the ring is significantly bluer than the ring, consistent with the ring serving at the "birth ring" of the smaller grains in the halo. We measure the scattering phase functions: in the probed scattering angles, the grains in the halo are both more forward- and backward-scattering than the ring. We measure a surface density power law index of ~–0.7 for the halo, with local variations suggesting the slow-down of the radial outward motion of the grains. We present radiative transfer modeling to explain the observations.

Nickalas Reynolds (The University of Oklahoma)

John Tobin (NRAO)

Topics: Star and Planet Formation

Dynamics and Formation Mechanisms of Protomultiple, L1448 IRS3B

ALMA Cycle 4 (Band 7; 870 microns) observations of the nearby (d300 pc) triple protostar system, L1448 IRS3B, have resolved continuum spiral structure originating from an inner (80 AU) protostellar binary with a third companion embedded (230 AU) within one of the arms. Current observations and efforts have yet to fully characterize the kinematics of this multiple system, which is needed to confirm if gravitational instability (GI) of the disk formed the multiple system. The continuum spiral structure does not directly shed light on the disk kinematics but the molecular line emission provides a complementary view. We use the molecule $C^{18}O$ (J=3-2) to trace the warm (> 15 K), dense gas of the IRS3B disk, uncovering information regarding the kinematics therein. Simple PV analysis shows the protomultiple disk is consistent with Keplerian rotation about a central mass of 1.1 $M_\odot$ and the dust continuum is consistent with a disk mass of 700 M_J. We model the $C^{18}O$ visibilities using a radiative transfer code (RADMC-3D) in tandem with a Markov-Chain Monte-Carlo program (MCMC; emcee) to better constrain the protostellar parameters and examine the disk kinematics. Furthermore, we use similar methodologies to constrain the mass of the disk using the dust continuum. We further discuss the implications of our results with the formation of stellar multiples and theorize the mechanisms of GI formation in this archetypal system.

Karwan Rostem (NASA Goddard Space Flight Center)

SOFIA/HIRMES Instrument Team

Topic: Instrumentation

The High Resolution Mid-InfrarEd Spectrometer (HIRMES) Instrument

The HIgh-Resolution Mid-infrarEd Spectrometer (HIRMES) is the 3rd Generation Instrument for the Stratospheric Observatory For Infrared Astronomy (SOFIA), currently in development at the NASA Goddard Space Flight Center (GSFC), and due for commissioning in 2020. By combining direct-detection Transition Edge Sensor (TES) bolometer arrays, grating-dispersive spectroscopy, and a host of Fabry-Perot tunable filters, HIRMES will provide the ability for high resolution (R ~ 100,000), mid-resolution (R ~ 10,000), and low-resolution (R ~ 600) slit-spectroscopy, and 2D Spectral Imaging (R ~ 2000 at selected wavelengths) over the 25 – 122 μm mid to far infrared waveband. The driving science application is the evolution of proto-planetary systems via measurements of water-vapor, water-ice, deuterated hydrogen (HD), and neutral oxygen lines. However, HIRMES has been designed to be as flexible as possible to cover a wide range of science cases that fall within its phase-space, all whilst reaching sensitivities and observing powers not yet seen thus far on SOFIA, providing unique observing capabilities that will remain unmatched for decades [1].

[1] Richards et al. [*Journal of Astronomical Instrumentation, Vol. 7, No. 4 (2018) 1840015*]

Maxime Ruaud (NASA Ames Research Center)

Uma Gorti (NASA Ames Research Center/SETI Institute)

Topic: Protoplanetary Disks

A Three-Phase Approach to Grain Surface Chemistry in Protoplanetary Disks: Gas, Ice Surface of Grains and Ice Mantles

Although only a limited number of atoms and molecules have been observed in protoplanetary disks, high resolution observations with the Atacama Large Millimeter/Sub-millimeter Array (ALMA) have revolutionized their study. These observations indicate that local physical conditions strongly affect the molecular content of disks. Molecules such as N_2H^+, C_2H and H_2CO show ring-like structures suggesting an active gas-grain chemical coupling. Evidence for gas-grain chemistry has been further strengthened by the recent detection of two complex organic molecules, methanol and methyl cyanide.
In this poster I will show results obtained from new detailed models that solve for the thermal structure of the disk and implement a full gas-grain chemical network. The novel aspect of this framework is the use of a three-phase approximation; the gas, grain surface and grain mantle are the three phases, and the chemistry occurring at the surface and in the bulk of the ice are treated as two distinct phases in interaction. Based on these results, I will show that the radial and vertical variations of the physical conditions have a strong impact on the spatial distribution of these molecules and that ring-like structures for molecules such as H_2CO and CH_3OH are a natural outcome of these variations. I will show that complex organic molecules efficiently form at the surface of grains in the dense, shielded midplane of disks. Finally, I will discuss the impact of various disk physical parameters (such as the mass of the disk and the dust-to-gas mass ratio) on disk chemistry and the distribution of complex organics.

Devesh P. Sariya (National Tsing Hua University, Hsinchu, Taiwan)

Ing-Gue Jiang (National Tsing Hua University, Hsinchu, Taiwan)
Li-Hsin Su (National Tsing Hua University, Hsinchu, Taiwan)

Topic: Transiting Exoplanets

A Follow-Up Study of the Transiting Exoplanet HAT-P-12b

HAT-P-12b is a sub-Saturn mass, mildly irradiated, H/He dominated planet with a low density. The planet orbits a bright V~ 12.8 K4 dwarf with a period of ~ 3.2 days. In order to define a better ephemeris, we have conducted a follow-up optical photometric study of the system. Our analysis includes data from several ground-based telescopes along with publicly available previously published light curves. We will present the results on the determination of the orbital parameters of this exoplanetary system. We will also show the results of the transit-timingvariation analysis.

Andrew Shannon (The Pennsylvania State University)

Alan P. Jackson (University of Toronto)
Mark Wyatt (University of Cambridge)

Topic: Solar System/Protoplanetary Disks

Oort Cloud Asteroids Ain’t, When They’re Cracked Up, to Be or: How I Learned to Stop Worrying and Love the Grand Tack

If the Solar system had a history of planet migration, the signature of that migration may be imprinted on the populations of asteroids and comets that were scattered in the planets’ wake. Here, we consider the dynamical and collisional evolution of the inner Solar system asteroids which subsequently join the Oort cloud. We compare the Oort cloud asteroid populations produced by migration scenarios based on the `Nice’ and `Grand Tack’ scenarios, as well as a null hypothesis where the planets have not migrated, to the detection of one such object, C/2014 S3 (PANSTARRS). Our simulations find that the discovery of C/2014 S3 (PANSTARRS) only has a >1% chance of occurring if the Oort cloud asteroids evolved on to Oort cloud orbits when the Solar system was $\lesssim$ 1 Myr old, as this early transfer to the Oort cloud is necessary to keep the amount of collisional evolution low. We argue this only occurs when a giant ($\gtrsim$30 $M_{\oplus}$) planet orbits at 1~2 au, and this strongly favour a `Grand Tack’- like migration having occurred early in the Solar system’s history.

Patrick Sheehan (NRAO)

John Tobin (NRAO)

Topic: Protoplanetary Disks

Constraints on Embedded Disk Structures & Masses with ALMA/the VLA

Class 0 & I protostellar disks are thought to represent early stages in the lifetime of disks, when they are still embedded in their natal envelope. As such, they provide an opportunity to study the initial conditions of protostellar disks, before any significant disk evolution or planet formation has occurred. We have conducted a survey of Class I protostars, initially with CARMA but now continuing with ALMA & the VLA, to study the structure of their disks and measure their masses. We fit detailed radiative transfer models to our sample and find that Class I disks have similar structure to Class II disks, including several Class I disks with gaps, cavities, and other interesting substructures. Our measurements show that Class I disks are, on average, more massive than the older Class II disks. As such, Class I disks may be a better representation of the initial masses present in protostellar disks. These samples are, however, still small, so we have begun an effort to model all 330 Class 0 & I protostars from the Herschel Orion Protostar Survey that were observed with ALMA as part of the VANDAM Survey. When completed, this study will produce a comprehensive picture of the youngest protostellar disks. We will finish by presenting early results from this effort.

R. Y. Shuping (Space Science Inst.)

Catherine Espaillat (Boston Univ.)
Luke Keller (Ithaca College)
William Vacca (SOFIA-USRA)
Michael Sitko (Space Science Inst.)

Topic: Protoplanetary Disks

Mid-Infrared Variability in Spectra of Pre-Transitional Disk Sources AB Aur and MWC 758: Preliminary Results from SOFIA-FORCAST Observations

We present new infrared observations of the Herbig Ae stars AB Aur, MWC 758 (HD 36112), and HD 100546 from 5 to 38 micron using the FORCAST instrument on SOFIA. We compare the resulting low-resolution spectra (R = 200) to previous observations with ISO and Spitzer. Even though both AB Aur and MWC 758 are of similar type and age, and possess pre-transitional ("gapped") disks with spiral arms, the observed changes in the SED are somewhat different in each case. AB Aur displays significant variations in IR flux and spectral shape from 15 — 40 micron on decade-long timescales as well as small variations in the strength and shape of the silicate feature at 10 micron. AB Aur is known to be variable in the near-IR (JHK bands) as well which is likely due to changes in the structure of the inner disk. MWC758, on the other hand, displays a significant increase at near-IR wavelengths (5 — 8 mic) and relatively little change in the silicate emission feature or longer wavelengths since the mid-IR observations carried out in 2004 with Spitzer/IRS. Our observed mid-IR spectrum for HD100546 is nearly identical to previous observations by Sptizer/IRS (2006). We discuss the underlying models for mid-IR variability in HAeBe pre-transitional disks (including the "see-saw" effect) and their applicability to these two sources.

Garima Singh (LESIA, Observatoire de Paris)

Ryan Boukrouche (AOPP, Physics Department, University of Oxford, UK)
Anthony Boccaletti (LESIA, Observatoire de Paris)
Trisha Bhowmik (LESIA, Observatoire de Paris)
Clement Perrot (Instituto de Fisica y Astronomia, U. de Valparaiso, Chile)
Quentin Kral (Observatoire de Paris – PSL)
Julien Milli (ESO)
Johan Olofsson (Instituto de Fisica y Astronomia, U. de Valparaiso, Chile)
Johan Mazoyer (Jet Propulsion Laboratory)

Topic: Debris disks

Discovery of an Azimuthal Density Gradient in a Gas-Rich Debris Disk Possibly Related to a Massive Collision

The gas-rich debris disk of HD 141569, first discovered in 1999 with the Hubble Space Telescope in near-IR and later in visible revealed structures such as multiple rings and outer spirals that appear to be extended as far out as ~410 AU. Some of the observational highlights of this hybrid disk include: detection of a gas component (Thi et al. 2014, White et al. 2016), most of the IR disk luminosity arising from regions within 100 AU (Augereau et al. 1999a), detection of OI & CII cooling lines (Thi et al. 2014), detection of resolved CO gas emission features within ~50 AU (Goto et al. 2006, Miley et al. 2018) and a detection of an extended disk component between 46-116 AU (Konishi et al 2016). HD 141569 circumstellar environment is an appealing laboratory to understand both dust and planetary evolution and architecture. In 2016, we used one of the advanced ground-based direct imaging instruments, SPHERE, to probe the region inside 200 AU at near IR wavelengths (Perrot et al. 2016). Several non-uniform concentric rings were discovered inside the inner cavity (<100 AU). The brightest and innermost of the newly discovered ringlets located at 40 AU features a North-South asymmetry, aligned with the disk projected major axis. For this reason, the observed asymmetry cannot be explained by light scattering properties of the dust. We proposed instead, in Perrot et al. (2016), an azimuthal variation of the dust density. However, this interpretation is complicated by the post-processing techniques commonly used for scattered light disk observations in total intensity (e.g. Angular Differential Imaging), which particularly impact the shape and local photometry of extended objects (Milli et al. 2012). In 2017, we have acquired polarimetric data using the dual polarimetric imaging mode of SPHERE/IRDIS. We discovered that the Lorentzian azimuthal distribution of the intensity reported in the brightest innermost ring in Perrot et al. (2016) is significantly different in total intensity and polarized intensity. Assuming a model based on the massive collisions between planet embryos (Jackson et al. 2014) we found that both images can be described as a combination of a phase function and an azimuthal density variation which takes a Lorentzian profile peaking to the south-west of the ring. Therefore, the complementarity of polarimetric and total intensity images has allowed us to constrain the actual dust density distribution and to relate this morphology to a potential massive collision. In this talk, I will introduce the debris disk HD 141569 and present briefly the disk morphology understood so far. Then, I will introduce disk imaging modes of the SPHERE instrument and disk structure observed within 100 AU both in total and polarimetric intensity. I will then explain how we used a model of massive collision to constrain the azimuthal density variations and will provide a preliminary interpretation.

Sebastian Stammler (Ludwig Maximilian University Munich)

Joanna Drążkowska (Ludwig Maximilian University Munich)
Til Birnstiel (Ludwig Maximilian University Munich)

Topic: Protoplanetary disks

The DSHARP Rings: Signs of ongoing Planetesimal Formation?

Radial drift of dust particles is a long-standing problem in planet formation. Due to its pressure gradient, gas in protoplanetary disks is orbiting the central star with sub-Keplerian velocities. Dust particles, on the other hand, try to orbit with Keplerian velocities. They feel a headwind from the gas, lose angular momentum, and drift towards the star on short timescales.

Observations of protoplanetary disks, however, show more dust around protostars than models of circumstellar disks with radially drifting dust particles would predict. As a solution to this problem, pressure bumps have been proposed in the past, that can trap dust particles and prevent them from drifting towards the star.

And indeed, recent high resolution observations of disks with ALMA show dust trapped in ring-like sub-structures. As a surprising result, the DSHARP survey of disks showed, that all of their analyzed rings have optical depths between 0.2 and 0.5 – none of the rings is fully optically thick.

Since dust traps are thought to be locations of planet formation by converting dust pebbles into planetesimals, this can yield as an explanation for the peculiar optical depths: dust has been transformed into large bodies, reducing the optical depths in the rings.

To test this scenario in more detail, we implemented a simple method of planetesimal formation into our dust growth and disk evolution code DustPy. We found that planetesimal formation in dust traps could indeed explain the seemingly fine-tuned optical depths, that are observed in the rings of protoplanetary disks.

Karl Stapelfeldt (Jet Propulsion Laboratory, California Institute of Technology)

LBTI HOSTS Science Team

Topic: Debris Disks

The HOSTS Survey for Exozodiacal Dust: Observational Results from the Complete Survey

The goal of the HOSTS (Hunt for Observable Signatures of Terrestrial Systems) project is to assess the risk imposed by exozodiacal dust to future space missions attempting to directly image habitable exoplanets. Our nulling interferometric observations in N band trace the thermal emission of this warm dust near the habitable zones of the host stars. The survey has recently been completed after observing 38 stars. In this paper we present and statistically analyze our complete data set. We put the strongest constraints available to date on the incidence rate and typical levels of exozodiacal dust around a sample of nearby stars. We find that 75% of the surveyed stars show no extended emission and are therefore not very dusty; that the presence of dust in the habitable zone correlates with the presence of cold outer dust for the more luminous stars in the sample; and that the underlying distribution function of dust levels is probably bimodal across the population of sun-like stars. The median dust level is 4.5 +7.3 -1.5 zodis. A future direct imaging mission can robustly conduct observations of rocky planets in the habitable zone against this level of background light if telescope apertures >= 8m are used; is viable for 4m apertures; but will be very difficult with apertures less than 4m.

Jordan Stone (University of Arizona)

Andy Skemer (UCSC), Phil Hinz (University of Arizona/UCSC), the LEECH team (various)

Topic: Exoplanet Demographics

The LEECH Exoplanet Imaging Survey: Limits on Planet Occurrence Rates under Conservative Assumptions

We present results fromthe largest L′ (3.8 μm) direct imaging survey for exoplanets —the Large Binocular Telescope Interferometer (LBTI) Exozodi Exoplanet Common Hunt (LEECH). We observed 98 stars with spectral types from B to M. Cool planets emit a larger share of their flux in L′ compared to shorter wavelengths, affording LEECH an advantage in detecting low-mass, old, and cold-start giant planets. We emphasize proximity over youth in our target selection, probing physical separations smaller than other direct imaging surveys. For FGK stars, LEECH outperforms many previous studies, placing tighter constraints on the hot-start planet occurrence frequency interior to ~ 20 au. For less luminous, cold-start planets, LEECH provides the best constraints on giant-planet frequency interior to ~ 20 au around FGK stars. Direct imaging survey results depend sensitively on both the choice of evolutionary model (e.g., hot or cold-start) and assumptions (explicit or implicit) about the shape of the underlying planet distribution, in particular its radial extent. Artificially low limits on the planet occurrence frequency can be derived when hot-start models are used exclusively, and when the shape of the planet distribution is assumed to extend to very large separations, well beyond typical protoplanetary dust-disk radii (~50 au). We place a conservative upper limit on the planet occurrence frequency using cold-start models and planetary population distributions that do not extend beyond typical protoplanetary dust-disk radii. We find that ~90% of FGK systems can host a 7 to 10 M Jup planet from 5 to 50 au. This limit leaves open the possibility that planets in this range are common.

Susan Terebey (California State University Los Angeles)

Lizxandra Flores Rivera (Cal State LA, IMPRS Heidelberg)
Karen Willacy (JPL/Caltech)
Neal Turner (JPL/Caltech)

Topic: Protoplanetary Disks

Modeling the Disk-Envelope Boundary around the Protostar L1527

ALMA probes continuum and spectral line emission from protostars that comes from both the envelope and circumstellar disk. For the protostar L1527 there is also spectral line emission that appears to trace the disk-envelope boundary. We present models of what ALMA should detect that incorporate a self-consistent collapse solution, radiative transfer, and chemical abundance calculations. Results for the outer disk show that there can be significant differences from standard assumptions due to the effect of CO freeze out, shocks, and non-Keplerian dynamics.

William Thompson (University of Victoria)

Christian Marois (NRC Hertzberg), Quinn Konopacky (UC San Diego)

Topic: Direct Imaging

Non-Detection of Additional Planets in Larger Orbits Around HR 8799

Of all the planetary systems that have been directly imaged, HR 8799 is the best studied. Though four gas giants have been discovered out to a radius of 68 AU, the system is known to host a large debris disk including a planetesimal belt extending between 100 and 310 AU. It is therefore worth searching for additional companions beyond the orbit of the furthest known planet, but none have so far been detected. In this work, we reduce the deepest integration yet of the system at L’ and large radii using a new optimized LOCI pipeline implemented in Julia and set strong upper limits on the existence of large planets out to a radius of 175 AU. This non-detection has implications for the study of debris disks and planet formation.

Nienke van der Marel (NRC Herzberg)

Topic: Protoplanetary disks

Clumpy Structures and Warps in an Almost Edge-On Disk

ALMA has revealed a large diversity of dust structures in protoplanetary disks, in particular multiple ring systems. However, some systems also contain asymmetric dust rings or ‘clumps’, which may have originated from a ring as well. We present new multi-wavelength ALMA continuum data of the RY Lup disk: a disk that is close to edge-on but still revealing the presence of a ring and a clump at 0.12” resolution, potentially caused by the presence of one or more hidden companions in the disk. Furthermore, the gas kinematics in ^{12}CO indicate that the inner part of the disk may be warped, and the scattered light images show spiral arms, which have both been linked to the presence of a companion as well. These new results place RY Lup in the growing list of disks which have been dynamically disturbed by companions. I will discuss the implications for our general understanding of the origin of gaps, misalignments and clumps in disks.

Geronimo Villanueva (NASA Goddard Space Flight Center)

Topic: Solar System

New Frontiers in the Exploration of Comets and the Origin of the Solar System

Comets are some of the best cryogenically preserved relics from the early solar system. Exploring their composition is therefore directly relevant to understanding the origins of our planetary system and to testing the hypothesis that small icy bodies have delivered prebiotic matter to early Earth. Ices are most sensitive to temperature and to radiation processing, and preserve key information of the processes (thermo/ion-molecule/photo-chemistry, radial-mixing, UV and X-ray processing) acting during the formation and evolution of our Solar System. By measuring molecular and element abundances and isotopic ratios in these primordial ices and by relating these to the stability regions of ices in the solar nebula (e.g., snow lines of H2O, CO2 and CO), we can better understand how our solar system formed.

In the last decades, we have seen a revolution in our understanding of comets, thanks to several in-situ missions (e.g., Rosetta, Deep-Impact, EPOXI) and astronomical studies of these bodies employing space (e.g., Herschel, HST) and ground-based observatories. High-resolution infrared spectrometers with broad spectral coverage at ground-based observatories (e.g., Keck, IRTF, VLT) and arrays of radio telescopes with state of the art receivers (e.g., ALMA) now permit the exploration of the kinematics, composition and thermal structure of a broad range of these bodies with unprecedented precision. These, combined with the advent of comprehensive spectroscopic databases containing billions of lines, accurate radiative transfer models, and unprecedented available computational power, are transforming the way we investigate comets.

In this talk, I will present a review of our current understanding of these primordial bodies, and how new capabilities will provide unprecedented exploration opportunities for exploring the origins of our Solar system.

Erik Weaver (Rice University)

Andrea Isella (Rice University)

Topic: Turbulence in Protoplanetary Disks

Measuring Turbulence in Protoplanetary Disks through Dust Settling

One of the key parameters in the planet formation process is turbulence, which governs dust settling as well as the growth of dust grains into planetesimals. Unfortunately, disk turbulence cannot be directly measured, and is difficult even to estimate. However, certain inclined disks offer a unique opportunity to constrain the dust settling and turbulence using a purely geometrical argument, comparing the scale heights of gas and dust. We use data from the recent DSHARP Large Program from ALMA to characterize the turbulence in several such disks.

Schuyler Wolff (Leiden Observatory)

Christian Flores (University of Hawaii at Manoa), Gaspard Duchene (Univ. of California, Berkeley), Karl Stapelfeldt (JPL), Francois Menard (IPAG), Marion Villenave (ESO, IPAG), Yann Boehler (IPAG), Christophe Pinte (Monash University), Gerrit Van der Plas (IPAG), Deborah Padgett (JPL), Will Fischer (STScI)

Topic: Protoplanetary Disks; Observations and Radiative Transfer Modeling

A Settled Protoplanetary Disk in Ophiuchus

As the earliest stage of planet formation, massive, optically thick, and gas rich protoplanetary disks provide key insights into the physics inherent in star and planet formation. We present multi-epoch HST observations (in F475W, F606W, and F814W bands) for the edge-on protoplanetary disk SSTC2DJ163131.2-242627; a young K5 star in the Ophiuchus star forming region. The data reveal the characteristic double nebulae structure for an optically thick disk viewed nearly edge-on in scattered light. The disk is remarkably flat and exhibits a slight left/right asymmetry that varies between epochs. We combine these data with an ALMA 1.3 mm continuum map and a spectral energy distribution compiled from the literature to investigate the geometry and dust properties of the disk using the MCFOST radiative transfer code. The spectral energy distribution constrains the mass and distribution of grain sizes within a disk, while the scattered light images and mm continuum map inform the geometry of the small and large dust particles in the disk, respectively. The disk is well characterised by a flared disk model with an exponentially tapered outer edge viewed nearly edge-on (within 5°), though some degree of dust settling is required to reproduce the vertically thin profile and lack of apparent flaring. We also discuss the temperature structure of the disk inferred from the scattered light disk models and relate it to high resolution ALMA CO observations.

Al Wootten (NRAO, University of Virginia)

John M. Carpenter (Joint ALMA Observatory), Daisuke Iono (National Astronomical Observatory of Japan), Leonardo Testi (European Southern Observatory), Nick Whyborn (Joint ALMA Observatory), Neal J. Evans (University of Texas at Austin)

Topic: Protoplanetary Disks

An ALMA Development Roadmap

A Roadmap, ALMA Memo No 612, has been developed for future development that will significantly expand ALMA's capabilities and enable it to produce even more exciting science in the coming decades. The development of this roadmap has been informed from advice on new scientific directions and the technical feasibility of possible future developments from the ALMA Science Advisory Committee (ASAC), the community (at meeting such as the present one), and from technical studies. A wide range of scientific studies will be efficiently enabled from several top development priorities, by significantly reducing the time required for their execution by increasing ALMA's sensitivity and its throughput. The Roadmap's plan is prioritized and commensurate with the anticipated ALMA Development Budget through the next decade. With this Roadmap, fundamental science drivers are identified:

- Investigation of the Origins of Planets, through imaging protoplanetary disks in nearby (150pc) star formation regions to resolve the Earth formation zone (~1AU) in the dust continuum at wavelengths shorter than 1mm, enabling detection of the tidal gaps and inner holes created by planets undergoing formation.
- Tracing the evolution from simple to complex organic molecules through the process of star and planet formation down to solar system scales (~10-100AU) by performing full-band spectral scans at a rate of 2-4 protostars per day
- Tracing the cosmic evolution of key elements from the first galaxies (z>10) through the peak of star formation (z=2-4) by imaging their cooling lines, both atomic ([CII], [OIII]) and molecular (CO), and dust continuum at a rate of 1-2 galaxies per hour.

These goals are ambitious and currently impossible even with the outstanding capabilities of the current array. To this end a group has been charged with incorporating these changes in the ALMA requirements. Specific improvements now in various stages of construction or planning to attain the goals identified in the Roadmap include:

- Upgrading the correlator to provide up to eight times more channels, providing increased spectral grasp for sensitive line studies (under construction),
- Commissioning higher efficiency modes, trading channels for efficiency, equivalent to adding 6 antennas to a 48-antenna array (under construction),
- At least doubling ALMA's processed bandwidth (under study), and
- Upgrading receivers in bandwidth and sensitivity (under study, examples follow).
    - Band 2: 67-90 GHz, 16GHz x 2 pol, has been built in NA; 67-116 GHz, 32GHz x 2 pol under study in EU.
    - Band 6: (211-275 GHz) ≥16GHz x 2 pol & lower noise under study in NA.
    - Band 7/8: (275-500 GHz) ≥16GHz x 2 pol & lower noise under study in EA.
    - High-bandwidth sampling and digital signal processing studies continue.

These upgrades enable the fundamental science drivers, making ALMA even more efficient and. They keep it at the forefront of astronomy by sustaining the production of transformational science and enabling fundamental advances in our understanding of the universe for the decades to come.

James Wurster (University of Exeter)

Matthew Bate (University of Exeter); Daniel Price (Monash University)

Topic: Protoplanetary discs

On the Formation of Protoplanetary Discs

Protoplanetary discs form during the star formation process. These discs may then fragment and dissipate, yielding a planetary system. However, the formation of these discs in numerical simulations has been fraught with difficulties once magnetic fields were included (Allen, Li & Shu 2003). It is known that stars, and hence these discs, form in strongly magnetised media (e.g. Heiles & Crutcher 2005), thus magnetic fields must be included in any disc formation simulation. However, discs typically failed to form in these simulations since the strong magnetic fields were too efficient at extracting angular momentum from the region around where the protostar was forming.

Over the past two decades, there have been numerous studies aimed at numerically forming protoplanetary discs in the presence of strong magnetic fields. These included varying the initial conditions and modelling the non-ideal magnetohydrodynamics (MHD) processes. Modelling both the charged and neutral gas yields a better representation of the region where stars and discs form, which is only very weakly ionised (e.g. Mestel & Spitzer 1956; Nakano & Umebayashi 1986).

In this talk, I will introduce the non-ideal MHD processes (Ohmic resistivity, ambipolar diffusion and the Hall effect) in the context of disc formation. Since each process affects a different region of the temperature-density-magnetic field strength phase-space, each process is important during different phases of disc formation and evolution. I will then discuss the effect that each process has on disc formation (e.g. Wurster, Price & Bate 2016), including the size and mass of the resulting discs and when they form. I will also discuss the conditions under which a massive disc can form early during the star formation process (Wurster, Bate & Price 2018c).

Once a disc has formed, then its size and longevity are important to determine if it will fragment and dissipate to ultimately form a planetary system. I will discuss our recent comprehensive parameter study that investigates disc properties and the probability of fragmentation (Wurster & Bate in prep). This will include a discussion on the importance of the initial amount of angular momentum, the initial magnetic field strength and geometry, and the inclusion of non-ideal MHD. I will discuss the parameter space under which large discs can form, and if and when these discs will fragment. This discussion will yield insight into the parameter space in which protoplanetary discs can form and ultimately fragment to form protoplanetary systems.

Chao-Chin Yang (University of Nevada, Las Vegas)

Mordecai-Mark Mac Low (American Museum of Natural History/Flatiron Institute)

Anders Johansen (Lund University)

Topic: Protoplanetary disks

Diffusion and Concentration of Solids in the Dead Zone of a Protoplanetary Disk

The streaming instability is a promising mechanism to drive the formation of planetesimals in protoplanetary disks. To trigger this process, it has been argued that sedimentation of solids onto the midplane needs to be efficient and therefore that a quiescent gaseous environment is required. It is often suggested that dead-zone or disk-wind structure created by non-ideal magnetohydrodynami-cal (MHD) effects meets this requirement. However, simulations have shown that the midplane of a dead zone is not completely quiescent. In order to examine the concentration of solids in such an environment, we use the local-shearing-box approximation to simulate a particle-gas system with an Ohmic dead zone including mutual drag force between the gas and the solids. We systematically compare the evolution of the system with ideal or non-ideal MHD, with or without back-reaction drag force from particles on gas, and with varying solid abundances. Similar to previous investiga-tions of dead zone dynamics, we find that particles of dimensionless stopping time $\tau_s = 0.1$ do not sediment appreciably more than those in ideal magneto-rotational turbulence, resulting in a vertical scale height an order of magnitude larger than in a laminar disk. Contrary to the expectation that this should curb the formation of planetesimals, we nevertheless find that strong clumping of solids still occurs in the dead zone when solid abundances are similar to the critical value for a laminar environment. This can be explained by the weak radial diffusion of particles near the mid-plane. The results imply that the sedimentation of particles to the mid-plane is not a necessary criterion for the formation of planetesimals by the streaming instability.

Haifeng Yang (Tsinghua University)

Zhi-Yun Li (University of Virginia)
Ian Stephens (Harvard-Smithsonian Center for Astrophysics)
Leslie Looney (University of Illinois at Urbana-Champaign)
Akimasa Kataoka (National Astronomical Observatory of Japan)
Josep M. Girart (Institut de Ciències de l'Espai (IEEC-CSIC))

Topic: Protoplanetary disks

Origins of (sub)Millimeter Disk Polarization

Disk polarization in (sub)millimeter dust continuum is a rapidly growing field in the ALMA era. Its origin, however, is still under debate, and is likely to be both system-dependent and wavelength-dependent. To date, various systems were observed to show evidence for scattering-induced polarization, with a handful of examples favoring alignment-based mechanisms instead. I will first review how scattering-induced polarization works and why it has the potential to study the grain growth, as well as to probe dust settling, which is hard to do otherwise. I will then focus on the best studied system, the HL Tau system. At Band 7 (0.87 mm), HL Tau provides one of the best examples for scattering-induced polarization. However, as the wavelength increases, the polarization pattern gradually changes to an azimuthal pattern at Band 3 (3 mm). This azimuthal pattern is less likely to be induced by self-scattering and was initially proposed to come from the so-called radiative alignment mechanism. I will discuss the observational features assuming perfect radial radiative alignment of dust grains and explain how it fails to explain the polarization at Band 3 for HL Tau.

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Student

Inbok Yea (University of Delaware)

Topic: Debris Disk

Use of Archival IR Photometry for Photosphere Fitting to Avoid Saturated 2MASS Photometry and Better Characterize Debris Disks

To characterize debris disks, we must obtain good photometry in order to accurately fit stellar photosphere models for the host stars. For nearby bright stars, particularly those with K magnitude less than 5, obtaining good near-IR photometry with 2MASS is difficult because of issues with saturation. This is particularly a problem for debris disk detection and characterization because for those tasks, we rely on measuring photometric excesses on the Rayleigh-Jeans tail of the spectra, which 2MASS constrains. To accurately characterize debris disks detected with Spitzer, Herschel, WISE, and even the eventual JWST, we use alternative sources for IR photometry in order to avoid the use of saturated 2MASS photometry. In particular, we use NASA Catalog of Infrared Observations for IRJK photometry. For many stars, JK photometry is unavailable, but we nonetheless try to fill the gap with available IR and W1 (saturation corrected) photometries. Our goal is to obtain new photosphere models and re-analyze infrared excess detections for nearby, bright stars whose debris disks subtend large angles on the sky, making them suitable for resolved high contrast imaging such as GPI and SPHERE. A blackbody model is used to fit the excess flux using MCMC in order to estimate disk temperature and luminosity.

Yimiao Zhang (University of California, San Diego)

Gaspard Duchene (University of California, Berkeley); Quinn Konopacky (University of California, San Diego); Megan Ansdell (University of California, Berkeley); Thomas Esposito (University of California, Berkeley); Robert De Rosa (Stanford University); Brenda Matthews (NRC Herzberg)

Topic: Debris Disks

Characterizing the Debris Disk of Substellar Companion Host HR 2562 with ALMA

We present our results on determining the properties of the debris disk surrounding star HR2562 based on the first ALMA detection of the system. HR2562 and its brown dwarf companion, HR2562B, were the first discovered system where a substellar companion resided in a cleared inner hole of a debris disk, and hence they provide invaluable opportunities to study the direct interaction between the companion and the disk (Konopacky et al. 2016). The disk is observed to be nearly edge-on and well resolved with a signal to noise ratio of 36.2 and ~9 resolution elements across the disk. The observed disk is consistent with the previously marginally resolved Hershel image. We determine the disk properties by fitting the ALMA image with an MCMC routine that uses the MCFOST radiative transfer code. We find that the full extent of the disk is ~200 AU, and investigate a range of possibilities for the true size of the inner hole, which remains unresolved in our ALMA data. An inner radius comparable to the distance between HR2562B and its host star may be an evidence for dynamical sculpting. We also use the derived disk properties to shed light on both the formation history and the true mass of HR2562B.