CONTRIBUTED TALKS

Monday March 25, 2024 - MORNING SESSION - TOPIC 1

Invited speaker: Joan Najita (NOIRLab)
Title: Pebbles and Planetesimals to Planets and Dust

Protoplanetary disks are the starting point for debris disk evolution. I will review some of the known properties of protoplanetary disks, their possible connection to debris disk properties, and how observations of debris disks may lend unique insights into protoplanetary disk evolution and planet formation processes. As one example, the similar sizes and detection rates of the spectacular rings observed in protoplanetary disks and debris disks suggest that they share a common origin. New calculations illustrate how rings of pebbles and planetesimals can follow diverse evolutionary paths depending on their initial mass and planetesimal formation efficiency. By comparing these results with the known properties of disks, we are led to a simple picture in which large protoplanetary disks evolve into the known bright debris disks, with our Solar System following a distinct evolutionary path that originates in compact disks. Such comparisons lend insights into the efficiency of planetesimal formation and limit the existence of invisible disk reservoirs of solids.

Contributed talk by: Josh Lovell (Harvard-Smithsonian Center for Astrophysics)
Title: Protoplanetary disk dispersal: revealing the birth of debris disks around class III stars

Class III stars are those that from their mid-infrared excesses are understood to have only very recently lost (or be in the act of losing) their protoplanetary disks. As such, they offer unique environments to study the early evolution of planetesimal belts, and the dispersal of planet-forming material. Here I present new observations and analysis conducted with deep sub-millimeter imaging campaigns with the SMA in the Taurus star forming region (and, data pending) brand new observations of Solar-like stars in the Upper Sco star forming region with ALMA.

Contributed talk by: Eric Gaidos (University of Hawaii at Manoa)
Title: The Dynamic Hybrid Inner Disk of PDS 70

PDS 70 is a key system in studies of disk evolution and planet formation, but while its outer disk and two directly-imaged giant planets have been intensely scrutinized, much less is known about the ~10 au-wide inner disk which is only marginally resolved by ALMA. Infrared and sub-mm observations show the inner disk to be gas-poor, with low CO, but detectable CO2, and H2O. We present new and archival data showing the system to be highly variable on day- to year-long timescales, including evolution between dipper-like and ``scalloped" periodic variability in the optical, and the near-disappearance of infrared emission from the innermost disk for about one year. We model the disk's SED as a warm (<600K) component and hot (~1200K) component and explain this variability in terms of the motion of the disk inner edge relative to the co-rotation radius and the dust sublimation point, resulting in gas-bearing dust being ejected along magnetic field lines, trapped at the co-rotation radius, or completely vaporizing outside the disk edge. This variability is driven by time-dependent accretion, in turn driven by We propose that this inner disk is a hybrid mixture of outer disk gas, depleted by trapping of solids (including CO ice) at a pressure bump, leaking across the gap, plus dust, H2O, and CO2 from evaporating/disintegrating/colliding planetesimals that are stirred by protoplanets within the inner disk. This means that observations of material close to the star can probe the products of ongoing planet formation in this system.

Contributed talk by: Daniela Iglesias (University of Leeds)
Title: Disc evolution in intermediate-mass stars

The stellar mass range between 1.5 and 3.5 Msun presents a particularly interesting circumstellar disc evolution; most notably, it is dominated by the EUV/FUV photoevaporation regime on the pre-main sequence, it contains the majority of gaseous debris discs, and it also show trends with giant planet frequency. In a recent spectroscopic VLT/X-Shooter survey (UV to nIR), combined with WISE data (nIR to mIR), we identified 135 pre-main sequence intermediate mass stars (IMSs) in an unbiased sample of the Southern sky. Our sample, encompassing protoplanetary, debris and a significant number of discs between these two stages, shows IR excess evolution that differs from that seen for low-mass stars, exemplified by samples drawn from nearby star forming regions. We find that, in IMSs, the inner disc regions are vacated in their entirety and not through a gradual inside-out dissipation. We also investigated the presence of gas absorption features in our sample via optical high-resolution spectroscopy. This requires detailed comparisons to spectra of nearby stars to eliminate objects with foreground cloud absorption as cause of the absorption features.
In particular, we apply this effective method to one such disc, eta Tel, discarding the earlier hypothesis of disc wind as cause for absorption features.

Contributed talk by: Haochang Jiang (ESO; Tsinghua University)
Title: Formation of Planets and Debris Disks from Pebble Ring

Rings are a prevalent feature observed in both protoplanetary and debris disks, hinting at an intrinsic connection between them. In the protoplanetary disk phase, these rings serve as accumulation sites for pebbles, fostering planetesimal formation and subsequent planet assembly. We investigate the viability of planet formation inside ALMA rings, where pebbles are trapped either by a Gaussian-shaped pressure bump or through strong dust backreaction. Planetesimals are assumed to form at the mid-plane of the ring via the streaming instability. Through N-body simulations, we explore the growth of these planetesimals via collisional mergers and pebble accretion. The concentrated pebbles and the crystallized headwind within the ring enhance the efficiency of planetesimal growth by pebble accretion as soon as they are born, ultimately yielding the ring as an efficient planetary core factory. A broad and massive planetesimal belt is left at the planet-forming ring's location. Remarkably, the majority of directly imaged planets coexist with debris disks, exemplified by the four giants residing in HR 8799. The presence of a mean motion resonance chain and an ALMA-resolved debris ring beyond these four planets renders HR 8799 an ideal candidate for the application of our model. We will also present a dedicated model that the cores of these four giants originated within a planetesimal-forming pebble ring and evolved to their current state.

Monday March 25, 2024 - AFTERNOON SESSION - TOPIC 2

Invited speaker: Josh Lovell (Harvard-Smithsonian Center for Astrophysics)
Title: Debris disks observations from the far-infrared to millimeter: recent perspectives and future outlooks

Observations of debris disks in the far-infrared and millimeter provide unique insights into the structure, evolution, composition and dynamics of cold outer belts, at radii spanning 10s--100s of au. Whilst in the far-infrared, Herschel provided ground-breaking insights to typical disk properties, in recent years progress in these wavelength regimes has been dominated by longer wavelength sub-/millimeter observations, in particular ALMA. ALMA's high angular resolution and sensitivity has enabled resolved spatial mapping of now dozens of debris disks in their continuum dust and gas via CO observations, expanding on core discoveries made by the SMA, NOEMA and JCMT. New sub-/millimeter observations are now readily enabling the extraction of debris disk radial and vertical structures, and in many cases the first spatially resolved sub-structures in planetesimal belts, such as rings, gaps, and clumps.

In this talk I will broadly review the past decade of key insights and advances for debris disk observations beyond 40um. I will primarily focus on the most recent results and trends, and discuss the connections that have been made to our broader understanding of planetary system evolution, and planet-debris disk interactions. I will also discuss the future landscape for far-infrared to millimeter instruments and observations for debris disk science, covering planned science programs (e.g. ARKS), observatory upgrades (e.g., SMA, ALMA), and proposals for new space-based telescopes and ground-based facilities

Contributed talk by: Mark Booth (UK ATC)
Title: AtLAST, The Ability to Detect Faint Debris Discs

The Atacama Large Aperture Submillimeter Telescope (AtLAST) is a concept for a 50m single dish telescope with a 2-degree field of view sited on the Chajnantor Plateau and run on renewable energy. This next generation facility will provide a combination of high sensitivity, high resolution and fast mapping speeds. The AtLAST Consortium is nearing the end of a 3 year design study, involving in depth investigations into the site selection, telescope design, sustainable power generation, telescope operations and the science case. The strength of AtLAST will be cases where a large field of view and/or sensitivity to large-scale structure is crucial, including imaging our own Sun, mapping the dynamics of the galactic plane and conducting deep surveys of high redshift galaxies. In this talk I will summarise the status of the design study and demonstrate what AtLAST can do for debris disc science. For debris discs, the sensitivity to large-scale structure means that AtLAST can much more easily detect faint discs around nearby stars than interferometers that resolve out the emission. The large field of view means that AtLAST can rapidly survey star forming regions and investigate the birth of debris discs. With AtLAST we will be able to find new debris discs, conduct population studies and investigate the origins of debris discs. AtLAST will also improve our understanding of the Solar System's debris disc through studies of comets, asteroids and TNOs.

Contributed talk by: James Miley (Universidad de Santiago de Chile)
Title: 10 years of observing Beta Pic with ALMA

I will present an update to the 10 year journey of ALMA multi-wavelength imaging of one of the most famous debris discs; beta Pic. I will show new ALMA Band 3 observations that trace larger 'pebbles' in the disc and detect the CO(1-0) transition. Detecting multiple transitions of the CO molecule allows for tighter constraints to be placed on the nature of the disc's presumed secondary gas, these new observations mean that the disc is now mapped in CO (3-2), (2-1) and (1-0) which will be jointly analysed in this work. With coverage from Band 3 to Band 8 we can calculate spectral indices using observations sensitive to small and large grains. I will also present a spatially resolved calculation of spectral indices in the disc and attempt to characterise the dust throughout the disc, comparing and contrasting the famous clump to the rest of the disc. The properties of the dust in debris discs have long been used as clues to the properties of exoplanets that are present within the system and of their orbital configuration. We are now within the era in which the gas too can be used to characterise exoplanetary systems with a new level of precision, and beta Pic is an ideal target to demonstrate these capabilities.

Contributed talk by: Jay S. Chittidi (University of Colorado, Boulder)
Title: The Fabulously Resolved Fomalhaut Debris Disk: ALMA Reveals New Substructure

Fomalhaut is home to a narrow, eccentric debris disk (width=14 AU, e = 0.12) located at 136 AU that has been studied previously at optical, infrared, and millimeter wavelengths. Here, we present the highest resolution view of the disk to date using ALMA Band 6 observations with two pointings at apocenter and pericenter. The long baseline observations are imaged both alone and together with archival observations that fill in the remaining parts of the disk at comparable resolution as well as shorter baselines that cover the entire disk at nearly uniform sensitivity. We then fit the visibilities with a disk model that allows for a free and forced eccentricity using GALARIO and emcee. The residuals suggest a difference in the width of the disk at apocenter and pericenter possibly indicative of a radial eccentricity gradient discussed in Lynch & Lovell 2022.

Contributed talk by: **Patricia Luppe (Trinity College Dublin)**
Title: **A multi-wavelength view of HD 32297's edge-on debris disk**

I present an ongoing multi-wavelength analysis of the edge-on debris disk around HD 32297. This is a well-known gas-bearing debris disk system around a young A star, with one of the largest infrared excesses observed among main-sequence stars. The data include the first ALMA Band 10 (814GHz) observation of a debris disk, demonstrating the ability to probe a new dust-size regime at high resolution from the ground. I present a multi-wavelength joint-modeling approach that combines the high-resolution data of Band 7, 8, and 10, with unprecedented resolution as high as 50mas (6.5au). This will allow a detailed analysis of the vertical structure and show how it may vary across different wavelengths. These high-resolution datasets will set new constraints for the radial structure of the disk, to probe architectures and dynamics in the outer regions of this planetary systems.

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Contributed talk by: **Sebastian Marino (University of Exeter)**
Title: **The ALMA survey to Resolve exoKuiper belt Substructures (ARKS)**

Over the last 10 years, ALMA observations have transformed our understanding of exoKuiper belts. On one hand, dust continuum observations have constrained the morphology of belts revealing a great diversity in terms of belt radii, widths, and scale heights. On the other hand, CO observations have also shown that exoKuiper belts often contain gas whose origin and implications are still highly uncertain. Most of this progress, however, has been made through low-resolution observations that have prevented us from testing models and theories. This barrier is breaking as the ALMA large program ARKS is characterising 18 exoKuiper belts to understand their detailed radial and vertical structures as well as constraining the distribution and kinematics of gas. In this talk, I will give an overview of ARKS summarising the sample selection, main goals, observation strategy, status of the program and main preliminary results.

Contributed talk by: **Yinuo Han (University of Cambridge)**
Title: **The radial structure of debris disks in the ARKS ALMA program**

High-resolution surveys with ALMA have revealed that annular substructures (rings and gaps) are common in protoplanetary disks, however it is not clear whether this is also true for debris disks due to their lower surface brightness and therefore the tendency for observations to be obtained at lower resolution with ALMA. Lower resolution observations do not commonly reveal systems of rings with radial gaps in debris disks which, if true, prompts the question of where those gaps in protoplanetary disks went as these systems evolved. On the other hand, the handful of high-resolution debris disk images with ALMA do commonly resolve radial gaps, however this sample of only a few systems is insufficient to draw strong conclusions. Recently, the ALMA survey to Resolve exoKuiper belt Substructures (ARKS) was carried out to image 18 debris disks at high resolution to better understand the radial structure of debris disks.

Understanding the high-resolution radial structure is important both for testing planet formation models and for constraining planetary system architecture. In this talk, we will present the radial profiles of all debris disks in the ARKS program observed until the time of the conference (we expect this will be the full sample except one system). We will discuss the prevalence of radial substructures in debris disks, present any ongoing analyses on the presence of any correlations between radial features such as belt location and width with stellar properties and compare them with corresponding protoplanetary disk structures.

Contributed talk by: Brianna Zawadzki (Wesleyan University)
Title: Resolving Vertical Structures in Millimeter Debris Disk Observations with ARKS

Debris disks are tenuous reservoirs of dust and gas around main sequence stars which probe the critical time domain between planet formation (in protoplanetary disks at $\lesssim$10 Myr) and mature planetary systems (mostly detected at ages of Gyrs). Millimeter wavelength observations are particularly important for dust characterization; larger grains probed by these observations trace the dynamics of the system and are not strongly affected by radiation pressure and stellar winds. Dozens of debris disks have been imaged with ALMA at low resolution, but only a handful of sources have previously been observed with sensitivities and resolutions sufficient to detect substructure like rings and gaps. This is especially true for characterizing the vertical structure of debris disks, which requires high-resolution observations of highly inclined disks. Well-resolved vertical structure measurements at millimeter wavelengths provide direct insight into the degree of dynamical excitation within the disk, enabling us to infer the presence of a wide range of planets (down to Earth masses) and determine the prevalence of Neptune-like migration histories. The ALMA survey to Resolve exoKuiper belt Substructures (ARKS) is observing 18 debris disks at high resolution, including 8 highly inclined ($i > 75°$) sources, which we add to two archival sources for a uniform sample of 10 disks with well-resolved vertical structure at millimeter wavelengths. We will present the results of the ARKS vertical structure analysis, using this sample of high-resolution observations to measure debris disk scale heights, constrain their total masses, and confirm or rule out the presence of planets.

Contributed talk by: Sorcha Mac Manamon (Trinity College Dublin)
Title: First results from the ARKS Large Program: CO gas in debris discs in unprecedented detail

Collisionally-produced dust has long been observed in exocometary belts, but until recently these belts were thought to be gas free. One of ALMA's greatest discoveries, enabled by its unprecedented sensitivity, has been the presence of gas in now over 20 exocometary belts. This is likely a product of exocometary release, giving us access to the volatile composition of exocomets for the first time, though an alternative origin as a primordial remnant of protoplanetary disk gas has yet to be conclusively ruled out. In this talk, I will present the first gas results from the ALMA survey to Resolve exoKuiper belt Substructures (ARKS) ALMA Large Program, aimed at characterising 18 exoKuiper belts at unprecedented sensitivity and resolution. I will present the 12CO and 13CO spectrospatial distribution for all detected systems, and the deepest upper limits constraining the CO release and photo-destruction mechanism, as well as a comparison with substructure as observed in dust continuum. The spectrospatial resolution (down to 4.02 au, and 26 m/s) achieved by ARKS will also enable the first analysis of kinematics and intrinsic line shapes in gas-rich exocometary belts. This will allow us to search for substructures produced by the interaction between CO gas and adolescent planets, as well as reveal resolved CO abundances and excitation conditions, shedding light on the origin of the gas.

Tuesday March 26, 2024 - MORNING SESSION - TOPIC 3

Invited speaker: Schuyler Wolff (University of Arizona - Steward Observatory)
Title: Observations of debris disks: scattered-light to mid-infrared

Debris disks serve as important signposts for both stellar and planetary system evolution. Over the past decade, observations of debris disks from optical to Infrared wavelengths have demonstrated a large diversity in debris disk morphologies. Ground based high contrast imaging systems and the Hubble Space Telescope have imaged dozens of new debris disks in scattered light, probing the spatial and size distributions of the sub-micron dust. At longer wavelengths, thermal emission from the dust peaks in the infrared where solid state spectral features can further elucidate the dust properties. JWST now allows for unprecedented spatial and spectral resolution in the near to mid-IR and has already changed our view of several debris disk systems. In this talk, I will review notable debris disk discoveries in this wavelength regime and discuss future capabilities provided by e.g. the Nancy Grace Roman Space Telescope Coronagraph Instrument and the upcoming ground based 30-meter class telescopes.

Contributed talk by: Isabel Rebollido (European Space Agency)
Title: The Beta Pic disk through the eyes of JWST

Since the first imaging observation of the Beta Pic disk in 1984, the astronomical community has thoroughly investigated this system, finding large amounts of dust and gas, exocomets, and two planets. All of this makes it the perfect laboratory to investigate the dynamics and chemistry of the late stages of planet formation. The JWST GTO 1411 program was designed to investigate the dust component at near- and mid-infrared wavelengths, providing new insights on the dust morphology, composition, and distribution. The combination of the high sensitivity of the on board instruments with the 4QPM and Lyot coronagraphs allows for the most detailed images of the Beta Pictoris disk so far at this wavelength range, revealing new features and details in the dust distribution. In this talk, I will present JWST NIRCam and MIRI coronagraphic images, ranging from 1.82 to 23 microns. I will also summarize the analysis of prominent disk features observed for the first time, and compare it to previous ground and space based observations at multiple wavelengths.

<u>Contributed talk by:</u> Kadin Worthen (Johns Hopkins University)
<u>Title:</u> A JWST MIRI MRS view of Beta Pictoris

The young (~20 Myr old) star Beta Pictoris is host to a famous edge-on debris disk and two confirmed giant planets, Beta Pic b and Beta Pic c. We present new JWST MIRI MRS observations from the GTO 1294 program of the Beta Pic system. With JWST, we detect an infrared excess from 500 K dust in the inner few au of the system. Through PSF subtraction, we find that this hot dust population is seen to be spatially extended out to 20 au at 5 microns, resulting in a newly discovered population of spatially resolved hot dust in the Beta Pic system. For dust at 20 au to be hot enough to emit at 5 microns, it must be sub-micron sized grains that are subject to blowout from radiation pressure. The small dust particles driven out by radiation pressure may accrete onto the planet Beta Pic b on their way out. We estimate a dust accretion rate from the inner disk onto Beta Pic b using our MRS data and find that it is on the order of 10-12 Lunar masses per year. We also detect Beta Pic b through PSF subtraction and present the first mid-infrared spectrum of the planet, which contains a water absorption feature. We model the new MRS spectrum of Beta Pic b to constrain its atmospheric properties. We do not find evidence in the spectrum for an infrared excess from the planet, which is consistent with our small dust accretion rate estimate.

<u>Contributed talk by:</u> Christine Chen (STSci)
<u>Title:</u> The Spectroscopic Case for a Giant Collision in the beta Pic Debris Disk

The JWST Mid Infrared Instrument (MIRI) Medium Resolution Spectrograph (MRS) is providing the first opportunity to monitor the mid-infrared spectra of debris disks over a ~20 year baseline. Comparison of beta Pic's Spitzer IRS spectrum (obtained in November 2004) and MIRI MRS spectrum (January 2023) indicates that the short wavelength continuum emission has decreased over time and the 20 micron silicate emission features have disappeared. In addition, the 10 micron silicate emission feature has been evolving over time from more crystalline in Subaru COMICS observations obtained in December 2003 to more amorphous in January 2023. One plausible explanation (that explains all of these changes) is that there was a large collision before the December 2003 observations and that we have been observing the system as it returns to equilibrium ever since.

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<u>Contributed talk by:</u> Arin Avsar (University of Arizona)
<u>Title:</u> 26 Years of HST/STIS Scattered Light Imaging Of The Beta Pictoris Debris Disk

We present HST/STIS scattered light imaging of the debris disk archetype, Beta Pictoris. Using four epochs of data, taken between 1997 and 2023, we achieve the longest baseline and highest precision temporal comparison of the Beta Pic debris disk to date, measuring temporal surface brightness variations with sub-percent precision in high SNR regions of the disk. We measure surface brightness variations throughout the entire disk with the goal of probing signals from planet-disk interactions in the inner disk and probing the collisional history and azimuthal structure of the outer disk. Additionally, we find unexpected surface brightness variations below the western midplane, stretching over 100 au in projected separation. Finally, we show that temporal analysis and modeling using new and archival STIS data continue to inform and provide insights for future observations with JWST and the Roman Space Telescope.

Contributed talk by: Sophia Stasevic (LESIA - Observatoire de Paris)
Title: An inner warp discovered in the disk around HD 110058 using VLT/SPHERE and HST/STIS

The edge-on debris disk detected around the young, nearby A0V star HD 110058 shows features resembling those seen in the disk of beta Pictoris which could indicate the presence of a perturbing planetary-mass companion in the system. We investigated new and archival scattered light images of the disk in order to characterise its morphology and spectrum. Our work uses data from two VLT/SPHERE observations and archival data from HST/STIS. We analysed vertical profiles along the length of the disk to extract the centroid spine position and vertical height, and extracted the surface brightness and reflectance spectrum of the disk. We detect the disk between 20 au (with SPHERE) and 150 au (with STIS), at a position angle of 159.6° ± 0.6°. Analysis of the spine shows an asymmetry between the two sides of the disk, with a 3.4° ± 0.9° warp between ~20 au and 60 au. The disk is marginally vertically resolved in scattered light, with a vertical aspect ratio of 9.3 ± 0.7% at 45 au. The extracted reflectance spectrum is featureless, flat between 0.95 micron and 1.1 micron, and red from 1.1 micron to 1.65 micron. The outer parts of the disk are also asymmetric with a tilt between the two sides, compatible with a disk made of forward-scattering particles and an inclination of <84°. Dynamical models suggest an undetected inner planetary-mass companion on a mutually inclined orbit with the disk could explain the warp.

Contributed talk by: Tom Esposito (UC Berkeley / SETI Institute)
Title: New HST/STIS Detections of Complex Outer Structure for Seven Young Debris Disks

Resolved images of dusty debris disks trace the physical location of solid material orbiting a star, which may be dynamically perturbed by the gravitational influence of planets in the system and/or reshaped by catastrophic impacts between planetesimals. We used the HST/STIS coronagraph to survey ten young (10–25 Myr) planetary systems where prior near-infrared adaptive-optics observations from Gemini Planet Imager and SPHERE discovered scattered-light debris disks within two arcseconds of each star. The STIS optical observations are sensitive to the outer portions of each disk beyond 0.5 arcsecond, and we detect seven of the disks at projected stellocentric distances ranging from 35 to 770 au. Unexpectedly, five systems have complex morphologies that were not evident in the ground-based images. Among these are "offset bar", "double wing", and "fork" features. We will present our observations and brief analyses of these morphologies. We will also place these new findings into context as support for a recently proposed dynamical model wherein debris disk dust is produced by a catastrophic impact between two planetesimals followed by the rearrangement of small grains due to radiation forces.

<u>Contributed talk by:</u> **Minjae G. Kim (University of Warwick)**
<u>Title:</u> **Constraining the detectability of crystalline and amorphous water ice with JWST**

Water, vital for life's emergence and evolution, is abundant in the Universe, yet its presence in debris disks remains undetected. Understanding the evolutionary track of water within these disks is crucial for chemical insights into the regions where planets are formed. The JWST, with its advanced spectral and spatial capabilities, offers a unique opportunity to identify water in different regions of debris disks. Observation with solid-state 3 μm ice bands (2.7 - 2.8 and 3.5 μm for crystalline and amorphous ice features at 3.2 μm for crystalline ice features) will enable not only to search for ice but also constrain valuable characteristics of ice, primarily the ice fraction and the crystallinity of ice in debris disks.

<u>Contributed talk by:</u> **Feng Long (University of Arizona)**
<u>Title:</u> **The inner gas and dust in 50-Myr-old disks as revealed by JWST**

Recent studies have identified a new class of disks that surround late M type stars at ages of ~50 Myr and with spectroscopic evidence of active accretion. The presence of strong infrared excess and broad H alpha emission lines serves as distinct markers of gas-rich primordial disks. Given the typical disk lifetime of 3-5 Myr, their survival poses a challenge to our understanding of disk dissipation and planet formation around M dwarfs. On the other hand, their infrared excess levels are also consistent with a type of unusually dust-rich debris disks that are believed to have experienced a recent giant collision, which have more compatible ages. With our recently acquired JWST MIRI/MRS data, I will present the first characterization of inner disk molecular gas content at an advanced age of 50 Myr. I will also talk about the solid-state dust features in comparison with extreme debris disks, and discuss how these results may reshape our understanding of planet formation and evolution.

<u>Contributed talk by:</u> **Chen Xie (John Hopkins University)**
<u>Title:</u> **Characterizing debris disks via reflectance spectroscopy from ground and space-based observations**

Reflectance spectra of debris disks can provide complementary information on the dust grain properties, including typical dust size and composition. However, most of the high-contrast imaging studies of debris disks only focus on broadband imaging data, overlooking spectral analysis of the integral field spectroscopy data due to challenges in removing stellar contributions. In this talk, we will present the techniques for measuring the reflectance spectra of debris disks via ground and space-based observations. SPHERE/IFS has accumulated eight years of data, including disk observations and disk-free reference observations. To efficiently process them, we develop an accurate and efficient post-processing technique for the extraction of the disk reflectance spectrum. By combining reference-star differential imaging (RDI) and data imputation using sequential nonnegative matrix factorization (DIsNMF), we can avoid the self-subtraction effect and the over-subtraction problem, enabling the model-free recovery of disk images and their reflectance spectra. To demonstrate the performance, we apply RDI-DIsNMF to SPHERE/IFS data of a simulated disk, HR4796A, and HD106906. Nevertheless, the wavelength coverage of ground-based instruments (e.g., SPHERE/IFS) was limited by atmospheric absorption. Space-based instruments (e.g., JWST/NIRSpec) cover a broader wavelength range, probing unique solid-state features from volatile frosts, such as H_2O, at wavelengths of 1.5, 2.0, and 3.2 μm. We will further present a preliminary result of the reflectance spectrum (0.6-5.3 μm) of the HD181327 disk from the JWST/NIRSpec observation.

Tuesday March 26, 2024 - AFTERNOON SESSION - TOPIC 4

Invited speaker: Isabel Rebollido (European Space Agency)
Title: An overview of gas in debris disks

The presence of gas in debris disks is now widely accepted. Its origin is still debated within the community, but the hypothesis of a secondary origin remains the most popular one for the majority of systems. Multiwavelength observations have revealed different populations of gas in a significant number of systems, both stable and variable, indicating a stable component as well as sporadic release events (i.e. exocomets). The origin and characteristics of this gas can be key to understand and shape the planet formation process for terrestrial planets, and even have an impact on habitability.
In this review talk, I will discuss the range of gas detections in debris disks, and its relevance towards disk evolution and planet formation.

Contributed talk by: Kevin Daniel Smith (Trinity College Dublin)
Title: Determining the H_2/CO Ratios of Gas Rich Exocometary Belts: Primordial or Secondary Origins?

Exocometary belts were initially thought to be gas free, however with the improved sensitivity of ALMA and Herschel, gas has now been detected in over 20 disks. With this emerging information, a dichotomy has arisen between primordial (H_2-rich) and secondary (H_2-poor) origin scenarios. In essence it is unclear whether studies of gas in exocometary belts probes the chemistry of volatiles released by comets, or remnants of protoplanetary disks. Our study aims to break this dichotomy using VLT CRIRES+ near-IR high-resolution (R~100000) spectra to look for H_2 rovibrational absorption along the line of sight to the star in the edge-on disks around HD131488 and HD110058. This approach was chosen because H_2 molecular lines tend to require hotter temperatures than is expected in exocometary belts to be detectable via emission and thus we focus on ground state absorption from the H_2 2.22 micron line. These data combined with existing HST-STIS CO absorption data yield CO/H_2 abundance ratios, with SNRs sufficient to differentiate between protoplanetary (low) or exocometary (high) ratios. This first direct measurement of H_2 abundances will conclusively break the dichotomy and confirm (or contradict) a primordial origin for the gas, either way enabling a significant step forward in our understanding of gas disk evolution.

<u>Contributed talk by:</u> Aoife Brennan (Trinity College Dublin)
<u>Title:</u> Investigating the Origin of Gas in the Debris Disk around HD121617 using ALMA Observations

Debris disks, which form from protoplanetary disks after approximately 10 million years, were traditionally thought to be dust-poor and lacking in gas. However, recent ALMA surveys have identified gas in at least 20 debris disks. Understanding the origin of this gas is crucial for studying planetary system formation, evolution, and exocomet composition. This project analyzes newly acquired ALMA data to investigate the gas origin in the face-on debris disk around HD121617, focusing on the 12CO J=3-2 and 13CO J=3-2 emission lines. The debate centres around whether this gas has a secondary origin, resulting from collisions within the debris disk, or a primordial origin, as a remnant from the protoplanetary stage. The presence of H2 gas plays a pivotal role, as it dominates the gas mass in the primordial scenario but is present in trace amounts, if at all, in the secondary scenario. Therefore, determining the presence of substantial H2 gas is crucial for understanding the gas's origin. To accomplish this, we compare the excitation and kinetic temperatures. If they are equal, indicating local thermodynamic equilibrium (LTE), it suggests an H2-rich scenario (primordial origin). In contrast, a non-LTE scenario, determined through multi-line analysis, reveals gas density and constrains or sets an upper limit on the H2 amount, thus ruling out a primordial origin. In summary, our project aims to determine both the kinetic and excitation temperatures to resolve this uncertainty and conclusively establish whether the system is in LTE.

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<u>Contributed talk by:</u> Camille Bergez-Casalou (LESIA/Paris Observatory)
<u>Title:</u> Planet-gas interactions in debris discs: Observable outcomes

Since recently, consequent amounts of CO gas were observed in old debris disks which were expected to be gas-free. At this stage, planet formation already occurred and fully formed planets are expected to be evolving in these disks. In this presentation, I will show how these planets might form observable substructures in the gas of these debris disks. When a planet is embedded in a gas disk, it perturbs its normally keplerian velocity. The resulting perturbation, called a kink, has been observed in protoplanetary disks. I use hydrodynamical simulations with the FARGO3D code to estimate the structure of typical debris disks perturbed by the presence of planets of different characteristics (masses and locations). With the help of the radiative transfer code RADM3D coupled to the observing tool CASA, I am able to derive realistic ALMA synthetic images of the disks’ gas emission and show under which conditions these features can also be observed in debris disks. We find that, if the planet is far away in the disk and at least as massive as Jupiter, then such kinks can be observed. Some known debris disks are therefore ideal candidates to search for such perturbations. This method can lead to a new way to indirectly detect exoplanets at an intermediate stage during their formation.

Contributed talk by: **Paul Huet (LESIA, Observatoire de Paris)**
Title: **Thermal atmospheric accretion onto planets in the debris disc stage**

Since gas has recently been discovered in debris discs, the current model of planet formation and evolution doesn't take this late gas into account. However, planets have already been discovered in debris discs with significant amounts of gas (e.g. Beta Pic), and models predict that this gas can be regenerated for >100 Myr, 10 times longer than in protoplanetary discs. Because of this characteristic time, we use a one-dimensional thermal model based on the stellar structure equation instead of hydrodynamic codes to follow the atmospheric evolution of a planet during late gas accretion. An analytical model developed in this context suggests a very efficient accretion. However, this model can't account for many physical aspects. We are therefore developing a more complex numerical model to be more accurate. We will describe how we develop it, based on a method initially designed for describing atmospheric accretion in protoplanetary discs. This method had to be adapted to debris disc specifics constraints like a limited maximum accretion rate. We also need to determine the right level of complexity in our physical models, such as the radiative transfer description or the equation of state. The aim is to determine the influence of different parameters such as the core luminosity, the opacity of the gas or the initial conditions on the accretion rate and the atmospheric structure. We will then be able to present some preliminary results that we should be able to obtain by then.

Contributed talk by: **Cicero Lu (NSF's NOIRLab, Gemini North Observatory)**
Title: **Discovery of NIR Gas Emission with JWST/NIRSpec in a Debris Disk**

Studies using UV and optical absorption spectroscopy have discovered hot atomic gas close to the star, which indicates the existence of falling and evaporating bodies (exocomets) in a handful of debris disks. Reinforcing this, ALMA-based studies have also revealed tenuous cold gas in tens of disks. Exocomets are theorized to travel from exo-Kuiper belts through the terrestrial zone into the inner region of the debris disks, leaving hot, warm, and cold gas in their trajectory. We carried out a survey to search for signatures of warm gas due to exocomets in a sample of disks where hot and cold gas co-exist (JWST Cycle 1, PI: Rebollido, PID 2053). I will present NIRSpec observations of the debris disk HD 131488. We discovered CO emission in the NIR corresponding to ro-vibrational modes. This is the first time that CO fundamental emission has been discovered in NIR for a debris disk. We identified the existence of 12CO and its isotopologue 13CO emission lines, and our analyses show a non-linear trend in the rotational excitation diagram. This could indicate the existence of two populations of gas, warm and cold, where the warm gas has a more compact spatial distribution than the cold gas. Alternatively, this may be an optically-thick, UV fluorescence emission of CO gas. I will discuss our interpretations and the need for follow-up data to break degeneracies.

<u>Contributed talk by:</u> Meredith Hughes (Wesleyan University)
<u>Title:</u> Dynamical Masses of Debris Disk Host Stars

Gas in debris disks is important in many different ways, including as an opportunity to learn about debris disk host stars. This archival ALMA program uses all the existing ALMA CO emission data from debris disks to derive dynamical masses for a sample of 12 stars (the ones with sufficiently high angular resolution and signal-to-noise to make dynamical mass measurements feasible). We compare the dynamical masses with spectroscopic and photometric mass determinations and identify targets that present a challenge to existing models of young stars. We also note the surprising prevalence of asymmetric CO profiles in gas-bearing debris disks, comparable to the CO clump in the beta Pictoris disk, which is a likely indicator of recent gas production in many of these systems.

<u>Contributed talk by:</u> Riouhei Nakatani (Jet Propulsion Laboratory, California Institute of Technology)
<u>Title:</u> Gas-Rich Debris Disks' Origins in Slow Photoevaporation around Intermediate-Mass Stars

In the study of planet formation, a key goal is understanding how protoplanetary disks (PPDs) evolve into systems of planets and debris. Traditionally, PPDs are thought to last no more than 10 million years (Myr), as inferred from infrared, Hα, and UV observations. This age marks the transition from gas-rich PPDs to gas-free debris disks. However, recent observations have revealed over 20 debris disks harboring gas despite ages exceeding 10 Myr. These gaseous debris disks are found most often around A-type stars up to 50 Myr old. Our new radiation hydrodynamics simulations demonstrate that PPDs' gas can persist beyond 10 Myr around A stars if the disks become depleted of small grains compared to the interstellar medium. In such cases, photoevaporation operates slowly due to inefficient photoelectric heating and the host stars' weak EUV and X-ray emissions. The model also predicts disk lifetimes that align with the observed incidence of gas-rich debris disks versus host star mass. These results suggest the plausibility of the so-called primordial-origin scenario, although it has been thought to be unlikely.

Wednesday March 27, 2024 - MORNING SESSION - TOPIC 5

<u>Invited speaker:</u> Antranik Sefilian (University of Jena)
<u>Title:</u> Planet-Debris Disk Interactions: A Theoretical Tapestry

While the number of exoplanets has surged in recent decades, the exploration of the outer regions of planetary systems has lagged behind, primarily due to the limitations of current detection techniques. A promising, indirect avenue to bridge this gap is offered by debris disks –

exoplanetary cousins of our Solar System's asteroid and Kuiper belts. Debris disks, ubiquitous in planetary systems, encapsulate records of past and ongoing processes, including interactions with planets. Thus, deciphering debris disks serves as a unique lens to unravel the intricacies of planetary system formation, architecture, and evolution, and potentially unveiling hidden planets. In this talk, I review the theoretical landscape of planet-debris disk interactions, tracing its historical evolution and elucidating the diverse methods employed to constrain the presence and parameters of yet-undetected planets within debris-hosting systems. Specifically, I explore the existing theoretical tapestry designed to explicate commonly observed structures in debris disks, highlighting both its strengths and limitations. Emphasizing the often-overlooked role of disk gravity in shaping some of these structures, I then delve deeper into the potential insights that future detections or non-detections of planets, facilitated by instruments such as JWST, can provide regarding planetary systems.

Contributed talk by: Antoine Lacquement (Univ. Grenoble Alpes- IPAG)
Title: A Possible Extra Planet orbiting Beta Pictoris Based on Disk Observations

The Beta Pictoris system is a famous example of young planetary system. Studied for over 30 years, it is characterized by a dusty debris disk, in addition to the presence of two already known planets. This makes it a particularly interesting case for studying the formation and evolution of planetary systems at a stage where giant planets have already formed, most of the protoplanetary gas has dissipated, and terrestrial planets could emerge. Following Mouillet et al. (1997), who predicted the existence of Beta Pictoris b a decade before its discovery (Lagrange et al. 2009) based on the analysis of disk deformations, we explore the possibility of an additional planet orbing outside Beta Pictoris b, by modeling the inner cavity of the disk. Dynamical studies show indeed that the two existing planets are able to carve the planetesimal disk up to ~25 AU only, while various studies of the disk images (Augereau et al. 2001, Dent et al. 2014) rather suggest an inner disk cavity extending up to ~50 AU (Dent et al. 2014). We present an exhaustive study of the carving process of the disk with an additional planet to those already known. We use the N-body symplectic celestial dynamics code RMVS3 (Wisdom & Holman 1991, Duncan 1994). Our simulations indicate that an additional planet with low eccentricity and a mass ranging from 0.15 to 1 Jupiter mass, located between 30 and 36 AU, would be consistent with observations of an inner disk edge at 50 AU. We also explored hypotheses of high eccentricity and the presence of two additional planets instead of one, which under certain conditions could also account for these observations.

Contributed talk by: Tim Pearce (Warwick University)
Title: Are planets responsible for steep debris-disc edges?

We tend to assume that cold debris discs host unseen planets at their inner edges, akin to Neptune and the Kuiper Belt. Often the hypothesised planets were too small to directly detect, so their existence is unclear. However, any such planets would dynamically interact with debris, potentially leaving clues about their masses and orbits. One clue is the steepness of debris-disc inner edges. I summarise a recent work, where we numerically investigated how a sculpting planet would affect the steepness of a disc edge. We showed that, whilst many debris discs have edges that are too steep to be explained by just collisional-debris evolution, they are too flat to arise through simple sculpting by planets. This hints that the often-held picture, where low-eccentricity, non-migrating planets fully sculpt the inner edges of debris discs, may not necessarily be correct. I discuss the implications of this for the architectures, histories and dynamics in the outer regions of planetary systems; these include the possibilities that sculpting planets are still clearing their chaotic zones, that significant planet migration occurs, or that planets are simply not responsible for sculpting debris-disc edges. With JWST poised to reveal the best-ever constraints on whether planets lie near debris discs, our results will help put those data into context.

Contributed talk by: Carey Lisse (Johns Hopkins University Applied Physics Lab)
Title: Astrosphere-ISM-Disk Interactions in HD61005, The Moth

We report resolution of a halo of soft X-ray emission surrounding the ZAMS G8.5V star HD 61005 by Chandra ACIS-S. Located only ~37 pc distant, HD 61005 is young (100 +30/-50 Myr), x-ray bright, observed with edge-on geometry, and surrounded by dense Local Interstellar Medium material. All these properties aided our ability to resolve the system's 180 au wide astrosphere, the first time ever for a main sequence Sun-like star. The observed x-ray emission morphology is roughly spherical, as expected for an astrosphere dominated by strong stellar wind outflow. The Chandra spectrum of HD 61005 is a combination of a hard stellar coronal emission (T ~ 8 MK) at Lx ~ 6 x1029 erg/sec plus a softer extended halo contribution at Lx ~ 1 x1029 erg/sec dominated by charge exchange (CXE) lines like NeIX. HD 61005 is also known to harbor large amounts of circumstellar dust in a mm-sized particle dense ecliptic plane + extended “wing like structures” full of micron sized particles. While the dust wings are only a small fraction of the total sensible dust mass, they are direct evidence of a strong LISM-dust disk interaction due to a dense LISM. Since the Chandra CXE x-ray morphology does not track the planar dust morphology but does extend out roughly to where the base of the dust wings begin, we present a toy model of x-ray emission produced by CXE SW-LISM interactions, tracing out the edges of the astrosphere beyond which micron-sized dust is deflected under LISM ram pressure.

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Invited speaker: Torsten Löhne (University of Jena)
Title: Collisions in Debris Disks

When we imagine debris disks, we think about comets and asteroids, perhaps interacting with nearby planets - but all that we actually see is just tiny dust grains. One important effect that links the visible small and the invisible big is collisions. A cascade of collisions can grind down a km-sized planetesimal into micron-sized dust grains.
I will review how collisions shape both the spatial and the size distribution of the observed dust, and in turn, what that dust can or cannot tell us about the properties and evolution of the planetesimals.

<u>Contributed talk by:</u> Hiroshi Kobayashi (Nagoya University)
<u>Title:</u> Insignificance of Collisional Damping in Debris Disks

Debris disks are believed to be maintained by dust supply caused by collisional fragmentation. A collisional cascade grinds planetesimals down to observable dust. The evolution timescale of collisional cascades depend on the relative velocities of bodies, which are characterized by orbital eccentricities and inclinations. The collisional damping for eccentricities and inclinations are mainly determined by collisional timescales for similar sized bodies. However, collisional cascades are mostly controlled by mass-ratio collisions, for which effective collisional damping is unexpected. Therefore, we investigate the effectiveness of collisional damping via collisional evolution simulations in self-stirring planetesimal disks. Planets are formed in the disk and planetesimals stirred by planets begin a collisional cascade. The eccentricities and inclinations of bodies resulting from the collisional cascade are almost independent of the mass of bodies. Collisional damping is effective for smaller bodies due to high collisional frequency. Therefore, this result indicates the collisional damping is insignificant. The proper treatment of collisional damping will additionally be discussed in my talk.

<u>Contributed talk by:</u> Max Sommer (University of Cambridge)
<u>Title:</u> Zodi structures caused by eccentric sub-Earths: A model prediction

Planets are known to induce various structural signatures in the zodiacal disks they inhabit through gravitational interactions. Typical planetary signatures include warps, center offsets, rings, and clumps, which may be observed to infer the presence of the responsible companion. Here we report on a mirror-inverted crescent pattern arising in simulations of exozodis harboring a small, moderately eccentric planet – similar to Mars. We show that the structure is a result of an alternating apsidal alignment occurring in particles as they migrate the orbital region of the planet. With decreasing planet mass, resonant interaction as well as chaotic scattering through close encounters cease, giving way to a directed apsidal rotation in planet-orbit-crossing particles. We analyze the strength of the emerging pattern with respect to planet and disc parameters, and generate brightness maps for favorable configurations (assuming a collisionless disk), indicating that these features could potentially be observable in resolved exozodis.

<u>Contributed talk by:</u> Pedro Poblete Rivera (UGA)
<u>Title:</u> Self-gravity of debris discs can strongly change the outcomes of interactions with inclined planets

Drastic changes in protoplanets' orbits could occur in \rev{the early stages of planetary systems} through interactions with other planets and their surrounding protoplanetary or debris discs. The resulting planetary system could exhibit orbits with moderate to high eccentricities and/or inclinations, causing planets to perturb one another as well as the disc significantly. The present work studies the evolution of systems composed of an \rev{initially} inclined planet and a debris disc. We perform N-body simulations of a narrow, self-gravitating debris disc and a single interior Neptune-like planet. \rev{We simulate systems with various initial planetary} inclinations, from coplanar to polar configurations considering different separations between the planet and the disc. \rev{We find that except when the planet is initially on a polar orbit,} the planet-disc system tends to reach a quasi-coplanar configuration with low vertical dispersion in the disc. When present, the Zeipel--Kozai--Lidov oscillations induced by the disc \rev{pump the planet's eccentricity and, in turn, affect the disc structure. We also find that the resulting disc morphology in most of the simulations looks very similar in both radial and vertical directions once the simulations are converged.} This contrasts strongly with massless disc simulations, where vertical disc dispersion is set by the initial disc-planet inclination and can be high for initially highly inclined planets. The results suggest caution in interpreting an unseen planet's dynamical history based only on the disc's appearance.

Contributed talk by: Arcelia Hermosillo Ruiz (UC Santa Cruz)
Title: Nbody Simulations of an Inclined, Eccentric Planet and Exterior Debris Disk Show Asymmetric Structure Similar to AU Mic

Planet formation processes and late-stage evolution, just before planetary systems stabilize, directly influence the structure of a star’s debris disk. Debris disk observations show they can be asymmetric, wide or narrow, eccentric, or full of gaps. The M star AU Micriscopii debris disk has a series of large-scale structures that move away from the star at high velocities above the midplane and on the left side. More recent observations revealed a few more structures on the right side of the disk, localized below the midplane and moving toward the star. I will present a suite of REBOUND N-body simulations with various initial conditions to investigate the interaction between an inclined, eccentric planet and an external debris disk. We find that the dynamical interactions between the planet and disk are in agreement with the impulse approximation. The validity of this agreement depends on the inclination and eccentricity of the planet and the distance between planet and the inner disk. Our simulations include stellar wind forces that produce a variety of dust particle velocities. I will present preliminary results, showing similar asymmetric structure to the AU Mic debris disk due to a variety of initial parameters such as: planet semi major axis, planet inclination, planet eccentricity, debris disk inner edge distance, star mass, and more. We compare with AU Mic observations and find that our simulations produce qualitatively similar structures that may point toward an observational diagnostic for the dynamics of young solar systems.

Thursday March 28, 2024 - MORNING SESSION - TOPIC 6 & TOPIC 3 (Part 2)

Invited speaker: Bryce Bolin (Goddard Space Flight Center)
Title: Debris disks put into context: The Solar system as a debris disk

One of the goals of astrophysics is to understand the physical properties and volatile contents of the protoplanetary disk and the planetesimals that accreted in it. Asteroids and comets are the remnants of the original planetesimals that accreted in the original asteroid and cometary reservoirs located throughout the primordial solar system. The physical properties and volatile contents of asteroids and comets provide clues for the physical properties of their planetesimal parent bodies and the collisional processing that took place subsequent to their formation. Most asteroids and comets have followed a complicated evolutionary path where they escaped from the reservoirs and were dispersed through gravitational interactions with the giant planets. In addition to being dynamically processed, asteroids and comets have experienced collisional processing and thermal heating over their dynamical lifetimes. Therefore, testing the physical properties of the original planetesimals requires an understanding of how the physical properties and volatile contents of asteroids and comets have evolved in the different dynamical, collisional, and thermal environments they have experienced since their original formation in the protoplanetary disk.

Contributed talk by: Simon Anghel (Astronomical Institute of the Romanian Academy)
Title: Method of measuring the size of meteoroids from well-known atmospheric impacts

Cosmic objects, predominantly small meteoroids, frequently interact with Earth's atmosphere, and often go undetected due to their small size. This study delves into techniques for measuring the pre-atmospheric mass of meteoroids with known trajectories, some of which were the subject of successful meteorite recovery campaigns. Among the studied methods, we found that the radiated light of the meteoroid disintegration is the most accurate method of estimating its kinetic energy and pre-atmospheric mass. This relation can be used to calibrate other methods of estimating the objects mass (e.g. radio, infrasound). Ultimately, by constraining the size and frequency of small meteoroids, we can make inferences about the formation, evolution, and distribution of dust in debris disks around other stars, furthering our understanding of cosmic processes.

Contributed talk by: Grace Batalla Falcon (Universidad Diego Portales)
Title: Infrared absorption and opacities of meteorite dust from the Atacama Desert

Dust particles are the dominant source of opacity at infrared and (sub)millimeter wavelengths. While accurate dust opacities are crucial for modeling disks properties, their estimation is highly uncertain in this regime: dust opacities values used in models are mostly extrapolations in wavelength and grain sizes. In order to tackle this problem and resolve these caveats to help the astronomical community to make the most of the revolutionary JWST and ALMA observations, we have established the UDP Cosmic Dust Laboratory, the first one of its kind in Chile and Latin-America. We have started operations working on infrared measurements of meteorites from the Atacama Desert, planning to extend our opacity measurements to the submillimeter regime. Meteorites are the best analogs of the type of dust expected in protoplanetary and debris disks, and the most accessible samples from the Earth to study in the laboratory. The semiarid to hyper arid climates of deserts allows preservation and accumulation of meteorites. Being the driest desert in the world, the Atacama Desert shows an exceptional meteorite concentration per km2 that has remained hyper-arid for several Myr and has preserved meteorites for a long time with a very low erosion rate and slow chemical weathering. In this first study, I will present measurements of dust opacities of 23 meteorites, 3 carbonaceous and 20 ordinary chondrites (types H, L and LL) from the Atacama Desert. We correlated their infrared spectra (2-23 microns) with chemical composition and the grain size distribution.

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<u>Contributed talk by:</u> Raphaël Bendahan-West (University of Exeter)
<u>Title:</u> Investigating the population of planets in debris disc systems with gaps using JWST

In the last 5 years thanks to ALMA observations, we have unlocked the study of substructures within debris discs. Understanding the structure and morphology of these discs offers valuable insight into inferring the potential presence of planets in these systems. However, the direct detection of these putative planets remains a very rare occurrence. Now, with the enhanced sensitivity of JWST, there is an exciting opportunity to bridge this gap and detect the population of planets currently inferred by resolved ALMA observations. While only three debris discs have shown gaps so far, we are becoming more aware that these gaps might be common. Looking at our Solar System, where the population of giant planets is shaping the gap between the Asteroid and Kuiper belt, gapped exo-Kuiper belts could share a similar architecture. Alternatively, gaps could be carved by inner planets through secular resonances. In this talk, I will present JWST Cycle 1 MIRI 11um observations focused on the three known debris discs with gaps: HD107146, HD92945, HD206893. These observations are sensitive to planets near the inner edge of these discs and in the gaps. I will show how these observations combined with astrometric accelerations allow us to constrain the parameter space and the various scenarios that have been proposed as the origin of these gaps.

<u>Contributed talk by:</u> Yiwei Chai (Johns Hopkins University)
<u>Title:</u> New Observations of the η Tel System with JWST MIRI MRS

Observing young, multiple-body systems can provide an opportunity to gain insight into the processes by which dynamical interactions sculpt planetary systems. We present a new spectroscopic observation of the β Pic moving group member, η Tel A, along with its binary brown dwarf companion η Tel B, using the JWST Mid-Infrared Instrument Medium Resolution Spectrograph. We derive a new epoch of relative astrometry and orbital parameters for the companion, extending the baseline of astrometric measurements to 25 years and indicating that η Tel B is currently near the apocentre of a long-period, highly eccentric orbit. Due to its closeness to the η Tel A disk at pericentre, we expect the eccentricity of η Tel B to result in an observable disk asymmetry in the mid-infrared. Further work is needed to quantify the brightness of the North vs. South lobes of the disk, in order to better constrain potential companion-disk interactions. Additionally, we obtain the first 11-24 μm spectrum of η Tel B, indicating a bare photosphere.

<u>Contributed talk by:</u> Ramya Anche (Steward Observatory, University of Arizona)
<u>Title:</u> High-contrast polarimetric observations of debris disks through the Roman Coronagraph instrument

High-contrast polarimetric observations of debris disks help constrain the scattering properties in addition to improving the contrast ratio. The upcoming Nancy Grace Roman Telescope Coronagraph is expected to measure the linear polarization fraction of disks greater than 0.3 with an uncertainty of 0.03. One of the critical problems with polarimetric observations is the polarization aberrations generated due to the telescope and polarimetric optics, which introduces errors in measuring fainter polarization disk signals. A modeling pipeline was previously developed to simulate the polarization observations of brighter debris disks similar to HR4796A without accounting for polarization aberrations. Here, we present the simulated polarimetric disk images of fainter debris disks (<0.1mJy/arcsec2) through the Roman telescope and the HLC and SPC coronagraphs, performing photon-counting in EMCCD, incorporating polarization aberrations, jitter, detector, and speckle noise. The Point Response Functions are generated using FALCO for each orthogonal polarization state to account for the polarization aberrations. Finally, we compare the recovered polarization fraction of the debris disk with the input to demonstrate the polarimetric capability of the Roman Coronagraph.

<u>Contributed talk by:</u> Justin Hom (Steward Observatory/University of Arizona)
<u>Title:</u> Searching for Signs of Earth-Like Planets: Demonstrating the Potential of the Roman-Coronagraph in Resolving Exozodiacal Dust and Debris Disk Substructures

The high contrast imaging of habitable zone (HZ) exoplanets around our nearest stellar neighbors in reflected light is a key science objective for upcoming and proposed high contrast imaging observatories including the Roman-Coronagraph and the Habitable Worlds Observatory. Roman is expected to achieve less than 1e-8 contrast at 140 mas inner working angle, higher contrast than previous ground and space instrumentation. While this is not enough sensitivity to detect smaller terrestrial planets, Roman will be capable of resolving planet-induced substructures in ~0.1 mJy/arcsec^2 bright exozodiacal and inner debris rings. These systems will make for prime targets for ELTs and the HWO, which will be capable of detecting the planets that induce these atypical disk morphologies. To demonstrate this, we produce several simulations of Roman observations of debris disk systems sculpted from the influence of planetary companions, using analytic disk models. We utilize a radiative transfer modeling approach to retrieve these morphological properties and assess the power of Roman in dust disk characterization and identification of planet-disk interaction features from sub-Neptunian and terrestrial planets. Future work involves the use of dynamical disk models to simulate exozodiacal dust distributions. The results from this investigation will directly inform observing strategies and analysis approaches for future high contrast imaging instruments and are an important first step in the characterization of HZ disk structure, subsequently informing theories of planetary system architecture, dynamics, and formation.

Contributed talk by: Sai Krishanth Pulikesi Mannan (LESIA/Paris Observatory)
Title: NMF with GPUs; a faster way to better disks

We present a generalized NMF-based data reduction pipeline for high-contrast imaging, with an emphasis on debris disks. By using an adaptable preprocessing routine that works well with algorithmic masks and improper data, we can easily offload the computationally intensive NMF to the GPU which leads to a large speedup in processing times. Recent developments in NMF including data imputation, and its ability to preserve disk structure better than classical RDI and KLIP without overfitting in the forward modeling stage, show promise for disk imaging in future space missions and have demonstrated improvements in the analysis of archival data. We demonstrate this using data from the Hubble STIS coronagraph and the JWST MIRI four-quadrant phase mask. Additionally, we also share initial results of exoplanet detections using NMF.

Thursday March 28, 2024 - AFTERNOON SESSION - TOPIC 7

Invited speaker: Virginie Faramaz (University of Arizona - Steward Observatory)
Title: Exozodiacal Dust

The Zodiacal dust cloud in the Solar system and its extrasolar counterparts, called exozodis, are a peculiar type of debris disks detected in the close vicinity of stars, in the Habitable zone and below, sometimes even down to the sublimation radius. Therefore, their presence is best evidenced thanks to interferometric observations.
In contrast with warm and cold Asteroid and Kuiper belt analogues, this dust, exozodis cannot be replenished via a collisional cascade. Similarly to dust in debris disks, exozodiacal dust is subject to both radiation pressure Poynting-Robertson (PR) drag, as well as collisional grinding. However, due to the proximity to the star and the short orbital periods involved, a population of km-sized parent bodies in a collisional cascade will erode extremely fast. Hence, two main mechanisms have been posited to replenish exozodis: PR drag and comet evaporation. Yet, even these mechanisms present caveats and additional trapping mechanisms are expected to come into play.
In this talk, I will review this narrative in detail and point to the future of exozodiacal dust studies and observations, and how these will be crucially necessary to ensure the success of future missions dedicated to the detection and characterization of exoplanets in the Habitable Zone.

Contributed talk by: John Debes (STScI)
Title: SAG 23: The Impact of Exo-Zodiacal Dust on Exoplanet Direct Imaging Surveys

The first Study Analysis Group (SAG) of the ExoPAG, entitled “Debris Disks & Dust”, was completed ten years ago and highlighted the fact that dust similar to that of the Zodiacal Cloud in the Solar System, so-called exozodis, could have a significant impact on missions that plan to directly image exoplanets and characterize Earth-like planetary atmospheres. Exozodi disks, as targets of study in their own right, can elucidate the architecture and chemistry of terrestrial planetary systems.

In the intervening time from SAG 1, rapid advancements in instrumentation, theoretical understanding of debris disks and interplanetary dust, observational capabilities, and data reduction techniques have occurred that impact the detection of disks via thermal emission at mid-infrared wavelengths or via high contrast direct imaging in the visible and near-IR. The recent publication of the results from the HOSTS survey, which used nulling interferometric observations at 10 μm, demonstrated that exozodi systems exist around nearby stars to varying degrees and that the typical exozodi level is within a few orders of magnitude of the Solar System’s zodiacal dust, paving the way for current direct imaging exoplanet concepts.

It is important then to identify the key questions that remain unanswered so that the astronomical community can make the most of the planned launch of a visible light coronagraph on the Nancy Grace Roman Space Telescope, the construction of the next generation of ground-based instruments and telescopes, and any future direct imaging or mid-infrared interferometric missions (or both) as envisioned by the Astro2020 report and the ESA Voyage 2050 plan.

<u>Contributed talk by:</u>Yu-Chia Lin (University of Arizona)
<u>Title:</u> Hurdling Exozodiacal Dust Challenges in Habitable Exoplanet Direct Imaging: Harder Than Anticipated?

In the quest to capture direct images of exoplanets in habitable zones, we encounter a formidable challenge—the interference of bright exozodiacal dust, a confounder that significantly diminishes sensitivity. In this talk, we embark on a journey into the intricacies of direct imaging observations in reflected light, focusing on the impact of exozodiacal dust on vortex coronagraphs with varying charge numbers and disk inclinations.

As I delve into the simulations, I discover that even modest dust substantially causes bright background brightness within the habitable zone. Astonishingly, the luminosity of this dust can overshadow that of a Jupiter-like planet in a neighboring planetary system by over 2000 times in some extreme cases, posing an obstacle in our pursuit of understanding distant worlds.

My analysis highlights the crucial need to account for exozodiacal dust within the inner working angle (IWA), which is often overlooked in conventional studies. Not only does dust alter the contrast curve, demanding a reconsideration of optimal design, but the highly aberrated point spread function (PSF) near the IWA complicates post-processing mitigation strategies. Importantly, my findings reveal that, for high-inclination disks and regions just beyond the IWA, dust can diminish contrast by another factor of three, underscoring the significance of comprehensive exozodiacal dust considerations in mission planning.

The discussion will extend beyond the simple estimate of exozodi effects to explore how these phenomena alter the ideal vortex coronagraph designs for direct imaging. Additionally, we will touch upon the assumption of a smooth disk model and the potential complexities that may arise, introducing a layer of realism to my simulations.

<u>Contributed talk by:</u> Mark Wyatt (IoA, Cambridge)
<u>Title:</u> Exozodi population models and the prevalence of problematic levels of warm dust

The HOSTS survey has made significant advances in characterising the level of dust emission that is present in the habitable zone of nearby stars (Ertel et al. 2020). While detections were only possible at the >100 zodi level, showing that ~20% of stars have such dust, the non-detections and an assumption of the form of the distribution of exozodi levels were used to infer that the median exozodi level is an order of magnitude lower still. This talk will present the distribution of exozodi levels predicted from the amount of dust dragged in from outer belts due to P-R drag. That population of outer belts is constrained by far-IR surveys, and the amount of dust that leaks in towards the star can be characterised given assumptions about the dynamics. This shows that while this dragged in component could have evaded detection thus far, the distribution of exozodi brightness should turn up so that levels above that seen in the Solar system that may be problematic for exo-Earth imaging are common. Since this model also underestimates the dust levels seen to stars with detectable exozodi, it could be that the exozodi population is even brighter than predicted, although dust levels could be lower if there is an intervening planetary system that ejects the dust. In addition to presenting the model and its caveats, this talk will discuss the implications for exo-Earth imaging.

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<u>Contributed talk by:</u> Germain Garreau (KU Leuven)
<u>Title:</u> Constraining the exozodiacal dust disk around θ Boo with the LBTI

The A0V star θ Boo is a 500Myr old system which was observed by Spitzer and Herschel (at 70μm and 100μm respectively) and by the LBTI in 2017 and 2018 (at 11μm) in the context of the HOSTS survey [Ertel et al. 2020]. The observations done by the LBTI using nulling interferometry showed a clear emission excess from dust near the habitable zone of the star (0.441% +/- 0.083%) which is indicative of the presence of an exozodiacal disk of ~148 zodis. However, the previous observations of Spitzer and Herschel showed no sign of cold dust (~120K) or warm dust (~600K) in the system. The HOSTS survey demonstrated that the presence of an exozodiacal disk is strongly correlated with the presence of cold dust which is likely of astrophysical origin. The formation process of the exozodiacal disk of θ Boo is therefore unknown. A new observation of the target was performed in May 2023 at the LBTI with NOMIC (at 11μm). The data reduction of the new observation clearly shows an increase in the observed emission excess. The origin of this increase is studied in the context of a new NASA grant dedicated to the development of nulling interferometry for exozodiacal disks characterization. Several possibilities are considered like the presence of substructures in the disk or the different

UV plan samplings between observations. The presence of a giant planet near the Earth-equivalent insulation distance (EEID) could also partially explain this increase.

__Contributed talk by:__ **Kevin Ollman (Christian-Albrechts-Universität zu Kiel)**
__Title:__ **Impact of hot exozodiacal dust on the polarimetric analysis of close-in exoplanets/MATISSE observations of the Fomalhaut inner disk**

First part of the talk: Hot exozodiacal dust (HEZD) found around main-sequence stars through interferometric observations in the photometric bands H to L is located close to the dust sublimation radius, potentially at orbital radii comparable to those of close-in exoplanets. Consequently, HEZD has a potential influence on the analysis of the scattered-light polarization of close-in exoplanets and vice versa. We analyze the impact of HEZD on the polarimetric characterization of close-in exoplanets. As a starting point for our analysis, we defined a reference model consisting of a close-in exoplanet with a scattered-light polarization consistent with the upper limit determined for WASP-18b, and a HEZD consistent with the near-infrared excess detected for HD 22484 (10 Tau). This study is motivated in particular by the recently proven feasibility of exoplanet polarimetry. Second part of the talk: Using near-infrared interferometric observations with MATISSE, we detected for the first time the signature of HEZD around the nearby A4 star Fomalhaut in the bands L and M. A significant visibility deficit is observed with respect to the expected visibility of the sole stellar photosphere especially in the L band that is interpreted as the signature of resolved circumstellar emission. To constrain the morphology of the excess emission source, we present the resulting best-fit model parameters for 3 different dust distribution geometries (narrow ring, spherical shell, symmetric Gaussian circumstellar emission). Furthermore, we place these results in the context of previous Fomalhaut investigations with the VLTI/VINCI instrument in the K band.

__Contributed talk by:__ **Thomas Stuber (University of Arizona)**
__Title:__ **How much large dust could be present in hot exozodiacal dust systems?**

An infrared excess over the stellar photospheric emission of main-sequence stars has been found in interferometric surveys, commonly attributed to the presence of hot exozodiacal dust. In various analyses submicrometer-sized grains in the close vicinity to their host star have been inferred to be responsible for the found near-infrared excesses. But how many larger grains (above-micrometer-sized) could be present in addition to the submicrometer-sized grains while maintaining consistency with the observational constraints? The answer to this question is important in order to distinguish between various scenarios for the origin of HEZD and to better estimate its observational appearance when observed with future instruments.

__Contributed talk by:__ **Philippe Priolet (IPAG)**
__Title:__ **VLTI multi-wavelength characterization of the exozodiacal dust around Beta Pictoris**

The presence of hot dust in the inner regions of exoplanetary systems is common, with a detection rate of about 20% around nearby AFGK stars from near-infrared interferometric surveys. These exozodiacal dust clouds, or exozodi, are extrasolar analogues to the Solar System zodiacal cloud, although the dust density is several orders of magnitude higher and the spatial distribution might differ. The most likely mechanism to explain the presence of short-lived dust in these inner regions is the inward scattering of exocomets from an outer Kuiper-like belt by a chain of (low-mass) exoplanets. Since the discovery of its edge-on debris disk in 1984, Beta Pictoris has become a laboratory for studies on planet formation and planet-disk interactions, especially around the outer disk (from around 50 au to 1000 au). Nevertheless, the inner region (<4 au) remains fairly unconstrained. VLTI/PIONIER observations first revealed the presence of a small circumstellar emission in the H-band (accounting for 1-2% of the stellar flux) which is likely due to hot dust in the inner regions of the system. This emission was shown to be variable in time, and may be associated with the inflow of exocomets detected in transit and radial velocity data. To investigate the spatial distribution of this hot dust, its variability and its spectral energy distribution across a wide spectral range, we obtained PIONIER (H-band), GRAVITY (K-band) and MATISSE (L, M & N-bands) interferometric data. In this contribution, we present the analysis of these datasets and the methods developed to extract spatial information on the hot dust distribution.

Contributed talk by: William C. Danchi (NASA Goddard Space Flight Center)
Title: Determining the constituents of the hot dust close to stars forming the hot exozodi

New mid-infrared instruments like JWST/MIRI and VLTI/MATISSE provide opportunities to investigate the types of dust that make up the hot component of the exozodi emission for nearby stars. We discuss recent results from MATISSE, a spectro-interferometric instrument at the VLTI. MATISSE operates at L, M, and N bands combining beams from either 4 1.8-m diameter Auxiliary Telescopes (ATs), or 4 8.4-m Unit Telescopes (UTs), providing 6 visibilities and 4 closure phases at L, M, and N bands (simultaneously). Using multiple telescope configurations, images of the circumstellar material around these stars can be reconstructed (Lopez et al. 2022). We discuss recent results from two papers illustrating the potential of such instruments. First, the paper by Kirschlager et al. (2020) described the first hot exozodi detection around a nearby stars, kappa Tuc, with MATISSE at L band. The other is the recently accepted paper by Varga et al. (A&A, in press, 2024) on the discovery of iron-rich dust in the multi-ringed inner disk of HD 144432. In this paper, the MATISSE team provides indications that the warm inner regions ($r < 5$ au) of typical planet-forming disks most if not all carbon is in the gas phase, while iron and iron sulfide grains are major constituents of the solid mixture along with forsterite and enstatite. These results give insight into the nature of the dust very close to stars that make up the hot component of the exozodi, which can affect the performance of Habitable Worlds Observatory and other direct detection missions.

Contributed talk by: Vasuda Trehan (University at Albany, SUNY)
Title: Predicting Explanatory habitability

As space technology advances, the possibility of humans becoming an interplanetary species becomes more realistic. Companies like SpaceX and Blue Origin are working towards making space travel more accessible to people. With the help of space observatories like James Webb and Hubble telescope, we can now study multiple planets and gather data about them. Bayesian data analysis is used to predict the spectral features of extrasolar planets, which is a challenging task that involves forecasting spectral bin heights with multi-planetary parameters. Each bin is a function of all the parameters, and spline curves with defined knots are used to model spectral bin heights. This iterative process helps us better understand Bayesian techniques and aligns with the broader goal of characterizing extrasolar planets through innovative data analysis. Ultimately, this will help us to understand the habitability of Earth better.

Friday March 29, 2024 - MORNING SESSION - TOPIC 8

Invited speaker: Andrew Swan (University of Warwick)
Title: Exotic debris disks

Debris disks are a more diverse population than A-type stars would have you believe. I will review systems that don't fit the mould: unusual architectures, extreme disks with huge and variable infrared excesses, and debris orbiting evolved stars. I will give particular attention to the compact, warm disks around white dwarfs. Associated more with planetary destruction than formation, they are nevertheless a rich source of information on the latter.

Contributed talk by: Kate Su (University of Arizona - Steward Observatory)
Title: What are Extreme Debris Disks (EDDs)? Exploring different formation pathways of EDDs by linking the observed properties

The variable emission of young extreme debris disks (EDDs) provides a unique window to explore large-scale collisions in the terrestrial planet zone during the oligarchic and chaotic phases of planet formation. However, the discovery of ~Gyr-old EDDs beyond the era of terrestrial planet formation clearly suggests multiple formation pathways in explaining the EDD behaviors. Each of the formation pathways is expected to create different characteristics in the impact-produced debris – observable signatures in the small grains and the content of volatile gas species. In this talk, I will summarize the properties of EDDs in terms of the observed dust mineralogy and degree of variability in relationship to stellar properties (type, age and multiplicity), and shed more light on their formation pathways.

Contributed talk by: Jonty Marshall (ASIAA)
Title: Results of a volume-limited survey for variable near-infrared excess in main sequence stars

ASASSN-21qj is a distant Sun-like star that underwent a prolonged episode of deep dimming events lasting 150 days after no prior recorded variability. Multi-wavelength optical photometry of the dimming reveals the stellar dimming was consistent with a circumstellar cloud of submicron pyroxene dust grains. The dimming was preceded by a substantial near-infrared excess identified in NEOWISE 3.4 and 4.6 μm observations, implying dust temperatures ranging from 1800 to 700 K and a total circumstellar dust mass of around 10^-6 M_Earth. The origin of this extended, opaque cloud has been linked to either the breakup of a large exocometary body around 0.2 au from the star, or a collision between two ice giant planets at a separation of at least 2 au from the star. Another system, ASASSN-23ht, has recently been identified with comparable dimming, albeit without any associated infrared excess. Here I present an analysis of the light curve of ASASSN-23ht and constraints on the location and mass of dusty material responsible for its obscuration. Finally, I will present initial findings of a volume-limited search for main sequence stars with variable infrared excess from NEOWISE to determine the incidence of catastrophic events similar to that around ASASSN-21qj.

Contributed talk by: Brenda Matthews (NRC Canada)
Title: Extreme debris disks reveal underlying planetary companions

Scattered light imaging with extreme AO systems reveals varying but significant substructure in many debris disks. The Gemini Planet Imager imaged two dozen debris disks in H-band, with many also imaged in J- and K-band. I will present this ensemble of data and share the results from a consistent analysis of the entire sample for evidence of asymmetries likely to point to as-yet unseen planets. I will highlight the dynamical modeling done for one particular system, HD 111520, that exhibits four distinct types of asymmetry, and illustrate that at least two planets are needed to reproduce these observations.

Contributed talk by: Gergely Hajdu (Nicolaus Copernicus Astronomical Center, Warsaw, Poland)
Title: Circumstellar matter around RR Lyrae stars

We present the first detection of circumstellar dust around a sample of RR Lyrae stars, identified through their variable mean magnitudes in the OGLE survey, and confirmed by other data sets (MACHO, EROS-2, KMTNet). While other phenomena, such as blending with other sources, may lead to a similar change of the mean magnitudes of RR Lyrae stars, the unchanging light-curve shapes and amplitudes lead to an unambiguous separation between them and variable extinction from circumstellar matter. The extinction ratios calculated from the multiband light curves possess a wide range, hinting at a similarly wide variety of dust properties. We discuss the prevalence, implications and possible formation mechanisms of circumstellar matter around RR Lyrae variables, with special attention to its connection to binarity.

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Contributed talk by: Érika Le Bourdais (Université de Montréal and Trottier Institute for Research on Exoplanets)
Title: The Challenges and Pitfalls in Deciphering The Chemical Composition of WD1145+017's Disintegrating Asteroid

Debris disks orbiting white dwarfs are formed from disrupted planetesimals that become trapped in the star's gravitational field and are later accreted. They provide an insightful window into the fate of planetary systems. WD1145+017 stands out as a particularly captivating white dwarf since we can observe the real-time disintegration of a rocky body. I present the newest gas disk model for this system using the radiative transfer code SYNSPEC to reproduce the high-resolution spectroscopic data taken over the last eight years with the HST COS and Keck HIRES instruments. Additionally, I discuss how the disk complicates chemical abundance determination and its interpretation regarding the polluting body composition.

Contributed talk by: Ayaka Okuya (National Astronomical Observatory of Japan)
Title: A possible correlation between the metal pollution of white dwarfs and the "dirtiness" of their dust disks

A quarter to half of white dwarfs (WDs) have metals in their atmospheres (e.g., Zuckerman et al. 2010). They are thought to originate from minor planets that orbit WDs, enabling us to probe the solid composition of planetary bodies beyond the solar system. Dust disks observed around metal-polluted WDs could provide additional compositional insights through thermal emission spectra (Reach et al. 2009).
For several disk emission spectra, it is pointed out that pure silicate dust could reproduce the 10 μm silicate feature but falls short in explaining near-infrared emission at ~5 μm. On the other hand, materials (e.g., amorphous carbon, metallic iron, and FeO) with conductivity orders of magnitude higher than insulators (e.g., silicate) can have larger opacity at these wavelengths. In this study, we aim to identify the origin of the 5 μm emission by considering silicate dust that includes materials with significantly higher conductivity. We compare observed infrared disk spectra around G29-38 with those calculated from a disk thermal emission model (Chiang & Goldreich 1997). We find that dust containing metallic iron or FeO with abundances consistent with Fe:Mg:Si:O:C ratios in the WD atmosphere can successfully reproduce the disk emission at ~5 μm. This scenario also predicts that the Fe/Si ratio in the WD atmosphere should be positively correlated with the metallic iron/FeO ratio in the disk dust. We analyze observed disk spectra around other DA-type WDs and tentatively confirm this prediction.

Contributed talk by: Jay Farihi (University College London)
Title: A Transiting Debris Disk in the Habitable Zone of a White Dwarf

In 2022 we discovered irregular and persistent transit events towards a white dwarf, with an orbital period near 25 hr and corresponding to the habitable zone for this 7900K star. Yet perhaps the most confounding part of the discovery is the fact that there are exactly 65 dimming events, one every 23 min, that occur over the 25 hr orbital period, and both these periodicities appear to be stable over several years. I will provide an update on this enigmatic system, which exhibits atmospheric metal pollution, but no infrared excess with Spitzer or WISE. It is hoped that JWST may shed light on the disk orbit and the underlying geometry.

<u>Contributed talk by:</u> Laura Rogers (University of Cambridge)
<u>Title:</u> The white dwarf opportunity: which rocks and minerals make up a planet?

We live in an epoch of rocky planet discovery, but if we are to truly assess the habitability of these exoplanets, we need to understand what the rocks are made from i.e., their mineralogy. White dwarf planetary systems provide the optimal route to tackle the important question: 'which rocks and minerals make up a planet?' by making the link between composition and mineralogy: bulk composition of the planetary material from optical and ultraviolet spectra of the white dwarf atmosphere, and its mineralogy from infrared spectra of the accreting dust disk. This talk will answer: How do we link the bulk abundances to the mineralogy? What does this mean for rocky bodies and habitability? What do we know based on observations of white dwarf planetary systems so far?

<u>Contributed talk by:</u> Akshay Robert (University College London)
<u>Title:</u> The frequency of transiting planetary systems around polluted white dwarfs

The recent discoveries of transits around white dwarfs have provided a unique and exciting view into their circumstellar debris discs. This family of white dwarfs with transiting debris exhibits significant diversity, where some display line-of-sight gas absorption, are highly dynamic with large scale heights, and the most recent system was detected to have circumstellar material in the habitable zone, where a planetary surface can support liquid water.
At present, however, there are no constraints on the transit frequency towards polluted white dwarfs. I present a search for new transiting systems using high-cadence ground- and space-based photometry. The occurrence of these systems is constrained using simulations encompassing radii from dwarf to Kronian planets, with periods from 1h to 27d. These results show that the dearth of short-period, solid-body planets transiting polluted white dwarfs is consistent with engulfment during the giant phases of stellar evolution, and modestly constrain both dynamical re-injection of planets to the shortest orbital periods and cometary birth and survival around intermediate-mass stars.

<u>Contributed talk by:</u> Zach Vanderbosch (Caltech)
<u>Title:</u> A Census of White Dwarfs Hosting Transiting Planetary Debris

Signposts of planetary debris orbiting and being accreted by white dwarf stars has grown rapidly in the past 20 years. Atmospheric metal pollution is a common occurrence, accompanied on occasion by infrared excess, gaseous emission/absorption, and transits associated with a circumstellar debris disk. The small subset of white dwarfs that exhibit transits caused by circumstellar debris clouds can potentially probe a wider variety of evolutionary stages between the initial disruption event and the accretion of debris onto the white dwarf, with known systems having debris orbital periods between 4 hours and 100 days. Surveys like ZTF and Gaia have been prolific discovery machines for such sources, accounting for 18 of the now 21 known and candidate transiting debris systems, most of which were found in just the past 3 years. I will present a census of the current white dwarf transiting debris class, with a focus on detection and characterization efforts, while highlighting some of the observational puzzles associated a few individual objects.

POSTERS

(P1) Author: Jean-Charles Augereau (IPAG - Univ. Grenoble Alpes)
Title: Electric charging of exozodiacal dust grains and impact on their dynamics

The detection of hot exozodiacal dust by optical interferometry challenges our understanding of dust grain dynamics in the inner regions of extrasolar planetary systems. One possibility for the origin of this hot dust is exocometary supply. However, this may require excessively high dust-deposition rates, suggesting that dust trapping mechanisms near the sublimation zone could act to extend the lifetime of the dust, either due to gas drag or interaction with the stellar magnetic field, or a combination of both. Here, we revisit the electric charging model of dust grains orbiting a star as a preliminary step to further explore the dynamics of hot exozodiacal dust evolving in the stellar magnetic field.

(P2) Author: Oier Baraibar Larraza (Instituto de Astrofísica de Andalucía (IAA-CSIC), Granada, Spain)
Title: Searching for debris disks around the closest M-dwarf planetary-systems

Recently there have been great advances in the detection of exoplanets, with more than 5000 confirmed, increasing the knowledge we have of these stellar systems. As for our Solar System, we expect these systems to have reservoirs of residual gas and dust from planetary formation or dust produced by continuous collisions of larger bodies ("collisional cascade"). The study of debris disks has focused on young stars, but for mature stars, of the order of a few Gyr, as our Sun, we also expect to find this kind of disks. Questions such as the little known frequency of debris disks around M-type stars, the possible correlation between debris disks and low-mass planetary systems around this type of stars (as it occurs in G-type stars), or questions about how the dynamical evolution of the planetary system may help to disperse dust and larger bodies from the disk, this effect being greater in high-mass planetary systems, are the ones we try to address in this work through the observation of mm thermal emission of dust with ACA. On the other hand, from our radio observations we can estimate the mass, outer radius and inclination of the debris disks that we are able to detect and resolve. For now we have been able to do so in one of the three observed systems. Assuming coplanarity with the debris disk, the orbital inclination of the planets and a better estimate of their mass can be obtained, which is a very valuable information for exoplanetary studies.

<u>(P3) Author:</u> Alessandro Bressani (University of Arizona)
<u>Title:</u> ALMA Band 6 - ACA Photometric Survey of Debris Disks

In this poster, I will present preliminary findings from a small survey of debris disks conducted with the Atacama Large Millimeter Array. Our survey was carried out in Band 6 (1.3mm) and with the Atacama Compact Array (ACA), which offers resolution capabilities similar to those of Herschel. Our goal is not to resolve our targets, but rather to determine their fluxes at these longer wavelengths, so as to determine the index of their spectral slope. In turn, this will allow us, combined with data available from the literature, to study the dust size distribution and properties of these debris disks. Note that our targets have all been selected because there are clues that they host important disk-planet interactions (presence of gaps from the SED, cometary activity seen in the star's spectral lines).

<u>(P4) Author:</u> Geoffrey Bryden (JPL - Caltech)
<u>Title:</u> Disentangling the parent families contributing to our local Zodi

TBD

<u>(P5) Author:</u> Kenny Chan (Univ of Southern Queensland / Montana State University)
<u>Title:</u> The Planet Formation, Evolutions, Dynamic and The Effect on Habitable Zones for M Dwarfs

Habitable zones (HZ) were affected and determined during planetary system formation for the low-mass stars such as TRAPPIST-1 and Proxima Centauri. This is a very popular topic in search of life. The formation of the exoplanet system is poorly understood in the beginning and is actively being investigated. By using N-body simulations, we can discover more about the evolution models of M Dwarf systems. During the planetary system formation, the Asteroid belts and snowlines were formed around its host star by mass accretion. The location and range of the Habitable Zone (HZ) were also determined by determination of the snowline location. Exo-Jupiter or Neptune (if exist) help to disperse the dust around the disk to help form a habitable zone. Type I planet migration may help determine the location and range of HZ and the formation of territorial planets. JWST and ALMA will find out more about The formation of the protoplanetary Disk for the M star systems. A N-body simulation called Mercury6 Hybrid integration package software is used. Luyten's Star (GJ273) has 2 confirmed planets in total and they are very close and packed together, GJ273b is within the HZ with liquid water while GJ273c is a dry planet. By using these simulations, the study of exoplanet formation in its early stage will be much easier when we are using JWST and ALMA observation. Hence the system's dynamic and evolution were understood. In Theory, most planets should be around less than 1 Earth mass for an M dwarf.

(P6) Author: Daniel Cotton (Monterey Institute for Research in Astronomy)
Title: True grit: The size of dust from optical aperture polarimetry

Multi-band optical linear polarimetry has been used to characterise dust in the interstellar medium since the 1940s. In particular it reveals grain orientation and places strong constraints on particle size distribution. We have recently demonstrated its ability to do the same for a representative set of debris disk systems with a broad range of properties. This advance has been made possible by the advent of high precision parts-per-million polarimeters. Whilst imaging polarimetry is possible at infrared wavelengths -- and very useful for revealing disk structure -- in the optical we obtain the integrated polarisation of the whole system. This makes it very challenging to disentangle the interstellar and disk components. The task is made much easier, however, by using imaging measurements to recover the integrated disk polarisation in the infrared -- fixing a crucial datum; thus the two techniques are complementary. For the HD 172555 disk we were able to determine the particle size distribution and dust composition from polarimetry in conjunction with mid-IR spectroscopy and near-IR imaging polarisation measurements using 3D radiative transfer models. The result was a disk composed of much larger grains than implied by an astronomical silicate composition. Here we present a new analysis of the HD 377 system employing the same conjoined polarisation--scattered light--thermal emission analysis to determine a self-consistent set of dust grain properties.

(P7) Author: Ewan Douglas (UArizona)
Title: Prospects and technology for direct imaging of exozodi and disks from future space coronagraph

TBD

(P8) Author: Marc Friebe (AIU Jena)
Title: Formation of Gaps in Self-Gravitating Debris Disks: Secular Resonances in a Two-planet System

Spatially resolved images of debris disks have shown their different morphologies, including spirals or gaps. When explaining these phenomena, most models neglect the mass of the disk and focus on a massive perturber. We investigate the evolution of two interior eccentric planets and a coplanar massive debris disk, on a secular time scale. We take the disk self-gravity, as well as the coupling between the disk and the planets into account, but neglect the non-axissymmetric component of the disk self-gravity. We use a simple analytic approach, to show the change in eigenfrequencies of the two-planet-system and resonance location in the disk, compared to previously studied systems with either a single planet or a massless disk. We will discuss the formation of gaps, depending on the planet`s parameters, and the shape of the gap. These equations will give restrictions on planet or disk mass for a gap cleared in this way.

<u>(P9) Author:</u> Antonio Hales (NRAO)
<u>Title:</u> ALMA Observations of the HD 110058 Debris Disk

This study utilizes ALMA observations to investigate the young debris disk around HD 110058. The high-resolution (0.″3-0.″6) data detect the disk in 0.85 and 1.3 mm continuum, along with the J = 2-1 and J = 3-2 transitions of 12CO and 13CO. Notably, this debris disk is the smallest observed by ALMA around stars of similar luminosity. Confirming its close-to-edge-on orientation, as seen in scattered-light images, radiative transfer modeling is employed to analyze dust and gas properties. The dust density peaks at approximately 31 au, featuring a smooth outer edge extending to ~70 au. Remarkably, marginal resolution along the minor axis suggests potential vertical thickness, with an aspect ratio between 0.13 and 0.28. Comparatively, the CO gas distribution is more compact than the dust, possibly indicating low viscosity and a higher gas release rate at small radii, akin to the disk around 49 Ceti. Simulations support a secondary origin for HD 110058's CO gas mass and distribution, considering CO photodissociation, shielding, and viscous evolution. The study also suggests that gas densities could induce the outward drift of small dust grains in the disk.

<u>(P10) Author:</u> Carl Ingebretsen (Johns Hopkins University)
<u>Title:</u> Observing Volatile Ices in Debris Disks with JWST NIRSpec

JWST Cycle 1 GO program 1563 (PI: C. Chen) has observed three debris disks in search of solid-state water in scattered light. The disks observed were beta Pictoris, HD 181327, and 49 Ceti. Observed using the NIRSpec integral field unit (IFU) mode, these three disks were chosen for both being spatially resolved in scattered light and previously identified as ALMA CO sources. The goal of this work is to use high-contrast, reflectance spectroscopy to observe for the first time the three-micron water ice feature in debris disks and constrain the dust grain composition and size from the solid-state spectral features. Water ice has now been detected in scattered light in both HD 181327 and beta Pic. The spectrum of these two debris disks looks qualitatively similar to that of solar system TNOs. In addition, CO fluorescent emission has been detected in 49 Ceti.

<u>(P11) Author:</u> Deniz Kacan (Purdue University)
<u>Title:</u> Radiative transfer modeling of ices in young disks

In order to understand planet formation, we need to study different stages of disk evolution. Planet formation is thought to begin in Class I young disks circling newborn stars. Determining the chemical composition and distribution of both gas and solids across these disks is a crucial step to establish a connection between the formation history of exoplanets and their elemental composition. Ices in these disk environments are particularly important. The components that make up life as we know it are hydrogen (H), oxygen (O), carbon(C), and nitrogen (N). C,H and N are considered to be volatile, they exist in solid materials mainly at low temperatures, as ices. In addition to that, most chemical reactions in space that form some of the complex organic molecules happen in these ice frosts on dust grains. Moreover, snowlines, where gas material freezes out to become ice, seem to be favorable places to form planetesimals. Edge-on disk observations are valuable resources for constraining broad features of protoplanetary disks including ice compositions and their locations in the disk. For this reason, we work on the edge-on, embedded, Class I protoplanetary disk IRAS 04302+2247. ALMA has been providing significant information about gas in the disk. But for detecting ice properties and snowlines directly, JWST observations are necessary. Here, we are preparing a radiative transfer modelling of the system using radmc3d code, to better analyze images provided by upcoming JWST data and constrain some of the parameters related to disk and ice properties.

(P12) Author: Tom Kaye (Raemor Vista Observatory)
Title: Long persistence dust clouds around white dwarfs

For the past 6 years our team has been monitoring the dust clouds around the white dwarfs WD 1145+017 and J0328. Clouds seem to spontaneously appear in various spots around the orbit and will often remain there for weeks without dip duration becoming longer despite an expected Keplerian orbital shear. The hostile environment of the white dwarf suggests that the dust should ablate within days, so these long persistence clouds are enigmatic. The working hypothesis is that the clouds are caused by asteroid collisions which initiates processes of continuous dust but there has been little evidence to confirm this idea.

(P13) Author: Grant Kennedy (University of Warwick)
Title: Fast visibility modelling of ALMA data

vis-r is a method for modelling radial profiles of interferometric observations of asymmetric structures. It uses the Discrete Hankel Transform (DHT) to directly model visibilities. Posterior distributions for parameterised models of high resolution observations, such as those from the ALMA ARKS Large Programme, can be obtained in minutes on a laptop.

(P14) Author: Kellen Lawson (NASA Goddard Space Flight Center)
Title: First Scattered Light Detection of the Fomalhaut C Debris Disk with JWST/NIRCam

We present the first scattered light detection of the debris disk around the nearby M4V star Fomalhaut C using JWST's Near Infrared Camera (NIRCam) — adding to the very small number of M dwarf debris disks resolved in scattered light. With a total integration time of only 1.5h across two filters (3.6 and 4.4 μm), we recover the exceptionally faint disk — which manifests with a surface brightness of just ~1 μJy / sq arcsec (roughly 400 times fainter than AU Mic's disk). The radius and orientation of the disk in these data are generally consistent with prior measurements from ALMA. Though no companions are identified, the 4.4 μm data provide strong constraints on their presence — with sensitivity sufficient to recover sub-Saturn mass objects in the vicinity of the disk. This result illustrates the unique capability of JWST for studying elusive M dwarf debris disks and lays the groundwork for deeper studies of such objects in the 2–5 μm regime. As these wavelengths coincide with extremely favorable planet contrasts and span numerous notable scattered-light spectral features, including those of water ice, this capability has considerable scientific value.

<u>(P15) Author:</u> Briley Lewis (UCLA)
<u>Title:</u> Gemini Planet Imager Observations of a Resolved Low-Inclination Debris Disk Around HD 156623

HD 156623 hosts a high-fractional-luminosity debris disk, recently resolved in scattered light for the first time by the Gemini Planet Imager (GPI). We present new analysis of the GPI H-band polarimetric detection of the HD 156623 debris disk, with particular interest in its unique morphology. This debris disk lacks a visible inner clearing, unlike the majority of disks in the GPI sample, and is known to contain CO gas, positioning it as a candidate "hybrid" or "shielded" disk. We use radiative transfer models to constrain the geometric parameters of the disk based on scattered-light data and thermal models to constrain the unseen inner radius based on the system's spectral energy distribution (SED). We also compute a measurement of the polarized scattering phase function, adding to the existing sample of empirical phase function measurements. We find that HD 156623's debris disk inner radius is around 2 AU based on the system's SED.

<u>(P16) Author:</u> Ronald A. Lopez (University of California, Santa Barbara)
<u>Title:</u> The Peculiar warp of HD 110058's debris disk

To date, observers have found several debris disks containing unique morphological characteristics. Interactions between dust, radiation, planetesimals, and possibly planets, work in tandem to shape disks into distinct morphologies. Features such as asymmetries and warps can shed light onto large scale dynamical evolution. Here, we will discuss the morphological characteristics of the edge-on debris disk around HD 110058 as seen in near-infrared scattered light imaging by the Gemini Planet Imager. The presence of an asymmetric warp in the disk at a radius of 0.35 arcseconds (~38 AU) is revealed in PSF-subtracted total-intensity images, reminiscent of the disk around β Pictoris. We map and characterize the disk's warped midplane and discuss the results of scattered-light modeling intended to constrain the three-dimensional morphology of the warp. We propose that the complex morphology of the disk is consistent with the existence of dynamical perturbations due to a possible unseen planet.

<u>(P17) Author:</u> Attila Moór (Konkoly Observatory)
<u>Title:</u> Abundant sub-micron grains revealed in newly discovered extreme debris discs

Extreme debris discs (EDDs) are rare, peculiarly bright and warm circumstellar dusty structures around main sequence stars. They may represent the outcome of giant collisions occuring in the terrestrial region between large planetesimals or planetary
bodies, and thus provide a rare opportunity to peer into the aftermaths of these events. Here, we report on results of a mini-survey we conducted with the aim to increase the number of known EDDs, investigate the presence of solid-state features around 10 um
in eight EDDs, and classify them into the silica or silicate dominated groups. We identify four new EDDs and derive their fundamental properties. For these, and for four other previously known discs, we study the spectral energy distribution around 10 um by means of VLT/VISIR

photometry in three narrow-band filters and conclude that all eight objects likely exhibit solid-state emission features from sub-micron grains. We find that four discs probably belong to the silicate dominated subgroup. Considering the age distribution of the entire EDD sample, we find that their incidence begins to decrease only after 300 Myr, suggesting that the earlier common picture that these objects are related to the formation of rocky planets may not be exclusive, and that other processes may be involved for older objects (> 100 Myr). Because most of the older EDD systems have wide, eccentric companions, we suggest that binarity may play a role in triggering late giant collisions.

<u>(P18) Author:</u> Azib Norazman (University of Warwick)
<u>Title:</u> A Search for Transiting Exocomets in TESS Sectors 1-26

Exocomets are interpreted as analogues to comets in our Solar System. While there have been several detections of exocomet-like events using spectroscopic methods, searching for them in photometry are more challenging. However, there have recently been a small number of stars showing such behaviour thanks to the rapid advancements in large-scale surveys in the exoplanet field. The most prominent example of this is from the lightcurves of Beta Pic, a young A-type star. Recent literature has also indicated that exocomet detections are more likely in younger stars. As TESS carries out an all-sky survey, now is the opportunity to explore this hypothesis further and explore the occurrence rates of exocomets with relation to the spectral type of their host star, uncovering the occurrence rates as a function of spectral type and stellar age.
An automated method to search for exocomets was initially conducted with Kepler. However, necessary updates and considerations need to be conducted for the search with TESS. We present new exocomet candidates based on the results from our search. Building our knowledge of exocomets is extremely exciting, bridging the gap of exoplanetary systems with that of our Solar System, and whether these exocomet detections also indicate water delivery to their planetary counterparts. We present new exocomet candidates from the results of our search.

<u>(P19) Author:</u> Anas Salman Taha (University of Baghdad - College of Science)
<u>Title:</u> Protoplanetary disk around HD 179218

How the Habitable zones were formed at the beginning for the low-mass stars such as TRAPPIST-1 and Proxima Centauri? This is a very popular topic in search of life. The formation of the exoplanet system is poorly understood in the beginning and is actively being investigated. By using some computer simulations of the stars. We can discover more about the evolution models on TRAPPIST-1 and Proxima Centauri. During the formation, the Asteroid belts were formed around its host star by dispersion of the disk. What was the dynamic of the disk during the Habitable zone formation? Were exo-Jupiter and exo-Neptune (if exist) helping to disperse the dust around the disk to help form a habitable zone? Will planets still host life or have a habitable atmosphere during their formation with Planetary debris disk around? The formation of the protoplanetary Disk for M star system. James Webb Space Telescope and Roman Nancy Telescope will find out more. An additional planetesimal-driven model using software is used.

TRAPPIST-1 has around 7 Earth-moon-sized planets in total and they are very close and packed together, which all are closer than the orbit of Mercury back in our own solar system. By using these simulations, the study of exoplanet formation in its early stage will be much easier when we are using JWST and Roman Nancy Telescope. In Theory, most planets should be around less than 1M_Earth for a M dwarf, even if there might be a Neptune-Jupiter size orbiting around the M-type stars.

(P20) Author: Karl Stapelfeldt & Eric Mamajek (JPL / Caltech)
Title: The Connection between Hot Dust and Stellar Activity

Hot dust in the very inner regions of mature planetary systems has been mysterious ever since its first discovery nearly 20 years ago. Its lack of correlation with the presence of warm dust, with stellar type, and with stellar age has made its origin difficult to understand. A theoretical understanding of the hot dust population necessarily includes dust sources and sinks. A dust sink that has received relatively little attention is the effect of stellar winds on the presence of hot dust. In this contribution, we review what is known about stellar activity in the population of stars that have been surveyed to date for hot dust. We find a tentative anti-correlation between stellar activity and the presence of hot dust, namely that the convective stars showing hot dust excess tend to have low levels of stellar activity and thus weaker stellar winds. This could plausibly be explained by the stronger stellar winds of more active stars serving to sweep out dust populations nearest to the star. We will discuss how the physics of stellar wind interaction with hot dust can serve as a constraint on the dust properties and lifetimes.

(P21) Author: Amy Steele (Planetary Science Institute)
Title: Improving Circumstellar Dust Disk Modeling by Using Polluted White Dwarfs

There is evidence that most main sequence stars have circumstellar material originating from the asteroids and comets of their planetary systems. What are the compositions of these small objects, or planetesimals, around other stars? One way to answer this question is to use the less than 1% of white dwarf (WD) stars that have spectra polluted by signatures of circumstellar gas. As cosmic mass spectrometers, these WDs--through their spectra--reveal the chemical makeup of the disrupted remnants of their planetary systems. The revealed chemical abundance patterns can be used to inform the modeling of dust around other stars, even those like the Sun. A disk model for these systems should include both gas and dust, but modeling both simultaneously is nontrivial. There are many public codes available to model either gas or dust, but the radiative transfer code, Cloudy, can handle both, while also providing a wealth of information about the physical state of the system. Cloudy, however, requires dust (or grain) optical properties over a wavelength range that is difficult to find. Using the spread in mineral types observed around polluted white dwarfs as motivation, here we show how one can calculate and construct their own optical constant datasets for use in codes like Cloudy. Given the wealth and quality of chemical composition data available with these polluted WD systems and the pending high-resolution infrared spectroscopy that will soon be available with the JWST, now is the perfect time to revisit the optical constants used to model dust in circumstellar disks.

<u>(P22) Author:</u> Kate Su (University of Arizona - Steward Observatory)
<u>Title:</u> Debris Structure in the Vega System Revealed by JWST

As one of the first discovered debris disks, the Vega system is extensively studied, revealing complex debris structures: a hot excess peaked at near-infrared wavelengths (exo-zodi near the silicate sublimation snowline), a warm excess peaked at mid-infrared excess near the water snowline, and a prominent cold excess analogous to the dust emission in the Kuiper belt, and beyond that a halo of small grains discovered by Spitzer. The nature of the hot and warm excesses is unclear because it could originate from the in-situ asteroid-like belt(s), or from icy planetesimals scattering inward from the Kuiper-belt component. Distinguishing these possibilities is of great interest to expand our understanding of debris disks in general and to probe the presence of unseen planets around Vega. We present the sub-arcsec JWST images of the Vega system that resolve the inner warm debris distribution at 15.5 and 25.5 microns for the first time. We will discuss the origin of the warm debris in light of these superior images and the constraint they provide for the unseen planet(s).

<u>(P23) Author:</u> Berhe Tewelde Teklhaimanot (University of Vale do Paraiba)
<u>Title:</u> AF spectral type runaway star candidates in the 30 Doradus region of the LMC Using Gaia DR3

The relative proper motions of eight A-F type runaway candidate stars in the 30 Doradus (30 Dor) region of the Large Magellanic Cloud (LMC) were investigated using Gaia DR3. Three stars, ID 204988, 271782, and 358858 are fast runaways, and two stars, ID 325244 and 373715, are slow runaways in the tangential plane of the 30 Dor region with relative proper motions of $\mu \leq 3.92$ mas/yr with respect to their neighbors and $\mu \leq 4.05$ mas/yr with respect to the central cluster R136, which correspond to a tangential velocity of 920.58 km/s and 951.30 km/s, respectively. The remaining three sources, ID 223800, 346142, and 371614, could be unresolved binaries. Based on the calculated values of the flight time and relative proper motions, the stars ID 204988, ID 325244, 358858, and 373715 have proper motions and positions consistent with the runaway scenario from R136. The stars ID 204988, 325244, and 373715 have flight times from R136 agreed with ejection from the cluster more or less during the last half of the age of the cluster, whereas the star ID 358858 has flight times from R136 agree with ejection from the cluster during or shortly after the cluster is formed. The origin of the remaining one star, ID 271782, could not be R136 as it has a direction of motion different from the runaway scenario from R136, although its flight time to R136 agreed with ejection from the cluster.

<u>(P24) Author:</u> Kevin Wagner (University of Arizona)
<u>Title:</u> Searching for Planets around Nearby Debris-Hosting Stars

VLT/NEAR implemented the first mid-infrared (11 micron) exoplanet imaging system, ultimately reaching sub-Neptune sensitivities in 70 hours of observations of the nearby Alpha Centauri binary. We now aim to take this science and sensitivity to the next level by utilizing the full capabilities of the world's largest infrared imaging telescope – the Large Binocular Telescope (LBT). Here, we describe our pilot survey of nearby stars, with a particular focus on planet detection limits within debris-hosting systems.

<u>(P25) Author:</u> David Wilner (Center for Astrophysics | Harvard & Smithsonian)
<u>Title:</u> Elemental Abundances in Edge-on Gas Rich Exocometary Belts

An effective way to access the bulk composition of exocomets is through FUV spectroscopy of debris disks that are viewed edge-on, detecting absorption lines against the stellar continuum. We have obtained HST FUV spectroscopy of the 15 Myr-old A stars HD 110058 and HD 131488 that host highly inclined dust belts with radii 30-80 au, strong Na and Ca absorption in the optical from circumstellar gas, and CO emission seen by ALMA. These observations target many atomic (volatile and refractory) species over the wavelength range 1060 to 3040 Angstroms, with multiple lines per species providing constraints on their excitation conditions and temperature. Elemental (atomic) abundances are important to understand the composition of the gas, otherwise inaccessible due to the rapid photodissociation of molecules. We present modelling results for some of the main volatile elements, Carbon, Oxygen, and Sulfur, as well as preliminary compositional comparisons with the beta Pic disk and Solar System/interstellar comets, setting debris disk gas in the wider compositional context of icy bodies in planetary systems.

<u>(P26) Author:</u> Kadin Worthen (Johns Hopkins University)
<u>Title:</u> Vertical Structure of Gas and Dust in Four Debris Disk

We present a high-resolution iSHELL spectrum of the HD 32297 debris disk searching for fundamental CO absorption in M-band. We do not detect any CO absorption, which is surprising given the high CO mass and near edge-on inclination of the disk. We postulate that the non-detection could be because the scale height of the gas is small and the amount of CO along the line of sight is then not detectable. Using our CO column density upper limit from our iSHELL spectrum and assuming the gas is in hydrostatic equilibrium, we constrain the scale height of the CO to be less than 2 au across the radial extent of the disk in HD 32297. We also use this method to estimate the CO scale height of 3 other edge-on disks: Beta Pic, HD 110058, and HD 131488. We compare the estimated CO scale height of these systems to their millimeter dust scale heights from ALMA and find that there is a potential correlation between the dust and CO vertical structure. This is consistent with the scenario that the dust and the gas are of the same origin, however, there are other factors that can influence the vertical structure of gas in debris disks.

<u>(P27) Author:</u> Yanqin Wu (University of Toronto)
<u>Title:</u> Gaseous Debris Disks

TBD

(P28) Author: Inbok Yea (University of Delaware)
Title: Modeling the Shadow of the TW Hydrae Protoplanetary Disk

Protoplanetary disks have also been observed with asymmetry and non-axisymmetric structures. However, due to the gas-rich nature of the disk, the non-axisymmetric structures are shaped by turbulent gas viscosity. The result of such physical processes affects the shape of the spirals, gaps, and misaligned inclinations of the disk components. TW Hydrae is one such disk: HST observations have revealed nonaxisymmetric shadows projected onto the disk surface. While initially, it seemed like the disk might have only one shadow, further observations have revealed that there are two shadows. We hypothesized this is due to two inclined inner rings at different orientations, each revolving with different periods. To model the shadows, we used empirical radial dust distribution and the dust radiative transfer model MCFOST to create the synthetic images. Results indicate that while the two inclined inner rings can fully explain the rotation of the shadows, the changing depth of the shadows requires the ring inclinations to evolve, which is not possible unless the rings are being torqued by an unseen object. We posit that a contributing factor towards the shadows is spiral waves and clumps.