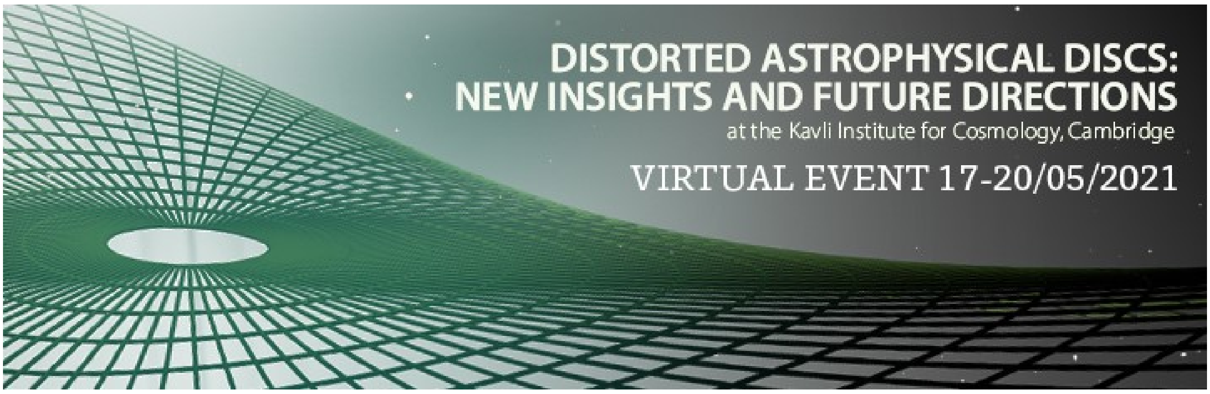

Talk Abstracts

Simon Casassus

Universidad de Chile

Warps in transition disks

Warps or inclination changes as a function of radius have often been invoked to explain protoplanetary disk observations. Well characterised examples can inform on the origin of such warps, on their role in disk evolution, and may allow for new probes of physical conditions. In transition disks, the separation of the inner and outer disks by a radial gap allows firm constraints on warp geometry. There are now 5 examples of sharply warped transition disks, in which the outer disk is directly exposed to stellar light. Some shadows also correspond to a temperature decrement, but others do not. After a brief description of the known warped systems, I will propose a simplified model for cooling in shadowed outer disks. This model accounts for the wide variety of thermal decrements, and may provide a diagnostic of the outer disk mass."

Chi-Ho Chan

Hebrew University of Jerusalem

Magnetorotational instability in eccentric disks

Eccentric disks arise in such astrophysical contexts as tidal disruption events, but it is unknown whether the magnetorotational instability (MRI), which powers accretion in circular disks, operates in eccentric disks as well. We examine the linear evolution of unstratified, incompressible MRI in an eccentric disk orbiting a point mass. We consider vertical modes of wavenumber k on a background flow with uniform eccentricity e and vertical Alfvén speed v_A along an orbit with mean motion n. We find two mode families, one with dominant magnetic components, the other with dominant velocity components; the former is unstable at $(1-e)^3 f^2 \lesssim 3$, where $f \equiv k v_A/n$, the latter at $e \gtrsim 0.8$. For $f^2 \lesssim 3$, MRI behaves much like in circular disks, but the growth per orbit declines slowly with increasing e; for $f^2 \gtrsim 3$, modes grow by parametric amplification, which is resonant for $0 < e \ll 1$. MRI growth and the attendant angular momentum and energy transport happen chiefly near pericenter, where orbital shear dominates magnetic tension.

Matthew Coleman

IAS

Spiral Density Waves Generated in the Boundary Layer

We examine the spiral density waves generated in simulations of the accretion disk-star boundary layer. These spiral structures are generated by the acoustic instability and can propagate far into the accretion disk, and are the predominant angular momentum transport mechanism in the boundary layer.

Janosz Dewberry

Canadian Institute for Theoretical Astrophysics

Rapid variability in eccentric accretion discs

Accretion disc eccentricities can drive a variety of secondary dynamical phenomena. The excitation of trapped waves by a distortion in the inner regions of a black hole accretion disc provides a promising explanation for high-frequency quasi-periodic oscillations (HFQPOs), ~50-500Hz fluctuations tied to the inner accretion flow in low-mass X-ray binary systems. I will discuss numerical investigations into wave excitation by an imposed eccentricity in relativistic accretion discs. These simulations exhibit for the first time the growth of trapped inertial waves in the presence of magnetohydrodynamic turbulence driven by the magnetorotational instability (MRI). The saturation of wave excitation involves additional non-linear interactions relevant to observations of multiple HFQPOs with distinct frequencies in some sources. While enhancing variability, sufficient eccentric distortion can also modify and in some cases suppress MRI-turbulence, an effect potentially related to the strength of the eccentricity gradient and/or twist.

Stefano Facchini

ESO

Linking inner and outer disks via photometry and high angular resolution imaging,

High angular resolution observations can access the inner few astronomical units of planet forming disks. In particular, scattered light images can probe the 3D geometry of the very inner regions, which affects the illumination pattern onto the outer disk. Complementary information is provided by ALMA, which can determine the gas kinematics of similarly small-scale regions. One unexpected result from these observations is that the inner regions of a subsample of protoplanetary disks are misaligned with respect to the outer disk, in particular in disks hosting large cavities at (sub-)mm wavelengths. In this talk I will show new high resolution observations (~3 AU) of a sub-sample of transition disks, all showing clear evidence of shadowing in both mm and NIR imaging. The optical light curves of these transition disks all show significant variability, indicating warped inner regions at ~0.1 AU scales from the star. These observational results are in remarkable agreement with hydrodynamical and radiative transfer model of systems hosting a sub-stellar companion dynamically clearing the disk cavity.

Boris Gansicke

Warwick

Planetary systems around white dwarfs: tidal disruptions and distorted dynamical discs

Planetary systems around white dwarfs are as ubiquitous as around main-sequence stars, and a key observational signature of these systems are compact debris discs resulting from the tidal disruption of planetary bodies. I will provide an overview of the current state of the observations of these systems, describe the general theoretical framework, and highlight some recent results regarding the dynamic nature of these debris discs.

Davide Gerosa

University of Birmingham

Warped accretion discs with LISA

The upcoming space mission LISA (Laser Interferometer Space Antenna) will measure gravitational waves from the inspiral and merger of supermassive black holes. If hosted in gas-rich galaxies, supermassive black hole binaries are expected to go through a prominent phase of gas-driven migration. This will not only promote the merger, but also leave a deep imprint on the black-hole spins. While black-hole frame dragging bends the surrounding discs into warped configurations, the discs react aligning the spins. We present a systematic treatment of distorted accretion discs in supermassive black-hole binaries, capturing the effect of warp and viscosity non-linearities on the spin alignment process. Spin orientations are promising gravitational-wave observables, imparting distinctive modulations to the emitted waveforms. Detection of black-hole binary spin precession with LISA will provide a unique opportunity to constrain the dynamics of warped gaseous discs.

Pavel Ivanov

PN Lebedev Physical Institute

The evolution of a twisted accretion disc formed after a tidal disruption event,

I am going to consider misaligned accretion discs formed after tidal disruption events occurring when a star encounters a supermassive rotating black hole. In such a case misalignment arises naturally, due to dynamic pressure exerted on the disc by the stream of gas lost by the star. I'll discuss the dynamics of such a disc and show that there are two characteristic regimes. At early times the disc inclination is nearly uniform at small radii where it is hot and its aspect ratio is large, the evolution of disc's inclination with time may be described as non-uniform precession. At later times the disc evolves through a sequence of quasi-static configurations. When disc's viscosity parameter is small, there is also a novel feature at the early times at the boundary between hot inner disc and cold outer disc - a sharp spike of inclination angle appears. Its physical nature will also be discussed. It will be shown that the largest inclination angles are expected during the time of disc transition from advective to radiative state.

Stefan Kraus

University of Exeter

Disk tearing in a young triple star system with misaligned disk/orbit planes,

GW Ori is a T Tauri-star triple system with an inner pair (242 day period) and an outer companion (4217 day period). We monitored the orbital motion of the system over the full 11 years period and derived a full RV+astrometry orbit solution, which reveals that the orbital plane of the inner and outer disks are misaligned with respect to each other. Furthermore, we image the circumtriple disk using ALMA, SPHERE, and GPI and discover three rings in thermal light and an asymmetric structure with radial shadows in scattered light. The inner-most ring (43 au radius) is eccentric and strongly misaligned both with respect to the orbital planes and with respect to the outer disk. Based on the measured triple star orbits and disk properties, we conducted smoothed particle hydrodynamic (SPH) simulations which show that the system is susceptible to the disk tearing effect, where the gravitational torque of the misaligned companion tears the disk apart into distinct rings that precess independently around the central objects. The ring might offer suitable conditions for planet formation, providing a mechanism for forming wide-separation planets on highly oblique orbits."

Rajika Kuruwita

University of Copenhagen

Simulating accretion and evolution during binary star formation,

I present theoretical work done using the AMR MHD code FLASH on the formation of binary stars and the evolution of their discs in these systems. I simulated the collapse of molecular cores until the formation of protostars and followed the early evolution of these systems. I investigated the influence that binarity has on the global evolution of a young stellar system, including looking at mechanisms such as accretion of material, jets and outflows, and dynamical interactions. I find that while in some scenarios binary stars may produce hostile environments for planet formation via the destruction of circumstellar discs, the formation of large circumbinary discs is possible. This can lead to the formation of planets around binary stars to be just as likely as the their formation around single stars. I also present preliminary results on the influence of eccentricity on episodic accretion, independent of separation.

Dong Lai

Cornell; TD Lee Institute

Circumbinary Accretion: From Supermassive Binary Black Holes to Circumbinary Planets

Circumbinary disks have been observed in a number of young stellar systems, and are the birth place for circumbinary planets found by transit surveys. They are also expected to exist around supermassive black hole binaries as a consequence of accretion from the interstellar medium following galaxy mergers. I will discuss recent works on circumbinary accretion, focusing short-term and long-term variabilities, and angular momentum transfer between the disk and the binary -- the result suggests that the long-standing notion of binary orbital decay driven by circumbinary disk may be problematic. Implications for planet formation/migration around stellar binaries will be noted. I will also discuss the dynamics and evolution of inclined/warped disks in binaries and connect with recent observations of protoplanetary disks and circumbinary planets.

Anna Laws

University of Exeter

Arms, rings and warps: Structured dust observed with GPI

I will present results of Gemini-LIGHTS (Gemini Large Imaging survey with GPI of Herbig/T-tauri Stars). This survey looked for dust discs around 44 stars, using the Gemini Planet Imager (GPI) to take high-resolution near-infrared polarimetric images. Many objects show busy circumstellar environments. The observed features include spiral arms, warps, rings, and more complex asymmetrical structures. I will discuss highlights from our survey, as well as radiative transfer modelling that attempts to further constrain and explain the properties of the observed dust structures.

Giuseppe Lodato

Universita' degli Studi di Milano

A dynamical measurement of the disc mass in Elias 2-27

A long standing problem in protostellar disc studies is providing an accurate measurement of the disc mass, that is a key feature to determine the amount of mass available for planet formation and the level of coupling between dust and gas. Traditionally, the disc mass has been obtained by applying an arbitrary conversion factor of 100 between gas and the more accessible dust mass. Alternative methods based on conversion of CO to H2 mass suffer from similar uncertainties. Here, I present a dynamical measurement of the disc mass in Elias 2-27, a source that is suspected to be self-gravitating based on its large scale spiral structure. From high spatial and spectral resolution kinematical data from ALMA observations, we obtain a rotation curve that shows significant deviations from Keplerianity and can be fitted by including the disc contribution to the gravitational field. We obtain a disc mass of 0.08+-0.04 Msun with a disc/star mass ratio equal to 0.17, consistent with the idea that the spiral structure is of gravitational origin. This dynamical measurement also allows us to gauge the gas/dust mass ratio in this source, that turns out to be ~ 80, slightly smaller but not far from the usual estimate.

Ann-Marie Madigan

University of Colorado Boulder

A Lopsided Solar System?

There’s something odd going on in our solar system. While the planets move on nearly-circular orbits in a well-defined plane, the minor planets beyond Neptune appear to cluster together in a highly-inclined, eccentric, and tilted structure. Astronomers have invoked the presence of an additional planet (Planet 9) or even a primordial black hole in explanation. In this talk I will show that these theories may be unnecessary. In analogy with spiral arms and bars in galaxies, the collective gravity of individually small but collectively massive bodies can create such structures in the outer solar system.

John Magorrian

University of Oxford

The eccentric disc of M31

The innermost few parsecs of M31 are dominated by a double nucleus, which is most naturally explained by Tremaine's (1995) model of an eccentric disc of old stars around a supermassive black hole. I describe ongoing work on the construction of a coherent picture of this system.

Uri Malamud

Tel-Aviv University / Technion Institute

A new hybrid SPH-analytical method for disc formation through tidal disruption of planetary bodies

We make use of a new hybrid method (Malamud & Perets, 2019) to simulate the long-term, multiple-orbit disc formation through tidal disruptions of rocky bodies by white dwarfs, at high resolution and realistic semi-major axis. We perform the largest suite of simulations for dwarf and terrestrial planets, spanning four orders of magnitude in mass, various pericentre distances and semi-major axes between 3 AU and 150 AU. This large phase space of tidal disruption conditions has not been accessible through the use of previous codes. We analyse the statistical and structural properties of the emerging debris discs, as well as the ejected unbound debris contributing to the population of interstellar asteroids. Unlike previous tidal disruption studies of small asteroids which form ring-like structures on the original orbit, we find that the tidal disruption of larger bodies usually forms dispersed structures of interlaced elliptic eccentric annuli on tighter orbits. We characterize the (typically power-law) size-distribution of the ejected interstellar bodies as well as their composition, rotation velocities and ejection velocities. We find them to be sensitive to the depth (impact parameter) of the tidal disruption. We discuss possible implications

Christopher Manser

University of Warwick

Why are gaseous debris discs around white dwarfs so rare?

White dwarfs accreting planetary material are essential in understanding the bulk compositions of exo-planets, and are fed predominantly by dusty discs formed by disrupted planetesimals. However, a rare subset of these discs (~5%) host a gaseous component, usually detected by the broad, double-peaked emission profiles of various ions (e.g. Ca II, O I, and Fe II). These gaseous debris discs around white dwarfs appear to have exciting properties such as high eccentricities (~0.3 – 0.5), as well as clear apsidal precession with periods from years to decades. I will present images of the planetary debris discs around two white dwarfs, SDSSJ1228+1040 & HE1349–2305; produced using a technique called Doppler tomography, and explain how these can be used to gain information about the structure of the disc as well as the host star. I will also discuss the possible origins of these discs and their relation to embedded planetesimals - such as the one I recently discovered with collaborators around SDSSJ1228+1040. I hope this presentation will spark discussions with both observational and theoretical researchers on why these gaseous components are so rare."

Rebecca Martin

University of Nevada, Las Vegas

Misaligned discs in and around binary star systems

Misaligned protoplanetary discs around one or both components of a binary star are commonly observed. In this talk I will explore the dynamics of such discs. A highly misaligned disc around one component of a binary star system may be unstable to Kozai-Lidov oscillations where the disc eccentricity and inclination are exchanged. A misaligned circumbinary disc may evolve to a polar state where the disc is perpendicular to the binary orbit. I will also explore the dynamics of circumplanetary discs that are unstable to tilting in the presence of the tidal torque from the star. Coupled with a spinning oblate planet, this can lead to a primordial planet spin-orbit misalignment.

Diego Munoz

Northwestern University

Long-Lived Eccentricities in Circumbinary Disks: Linear Theory and Simulations,

Accretion disks are able support slow eccentric modes that damp on very long timescales. Long-lived, finite disk eccentricities can significantly modify the gravitational coupling between the gas and binary companions (or other embedded bodies), playing a crucial role in the secular evolution of binary separations and eccentricities. Hydrodynamical simulations of circumbinary disks have consistently shown that significant eccentricities can develop in the gas, usually peaking near the edge of the tidally carved circumbinary cavity. However, it is not known with certainty whether these gas eccentricities are transient features, or if they correspond to truly long-lived standing waves (normal modes) in the eccentricity profile. In this work, we demonstrate via linear calculations and steady-state hydrodynamic simulations, that circumbinary disk develop long-term eccentricity profiles that correspond to trapped fundamental modes of the Schrodinger-type eccentricity equation. These modes are always prograde and exhibit apsidal precession with periods of a few hundred binary orbits. We show that the eigenfrequency and radial eigenfunctions (corresponding to the precession rate and eccentricity profile) of the trapped modes can be calculated from the background density profile, the disk aspect ratio, and the binary mass ratio. Long-lived disk eccentricities can (1) determine the (secular) dynamical coupling of binaries and disks, (2) modify the physical processes within protoplanetary disks, such as circumbinary planet formation, and (3) potentially leave observable imprints in the gas kinematics and disk morphologies.

Gordon Ogilvie,

DAMTP, University of Cambridge

Hydrodynamic theory of warped and eccentric discs

This review of theoretical approaches will be weighted towards the gas dynamics of non-self-gravitating discs. Linear and nonlinear secular theories of warped and eccentric discs, based on laminar hydrodynamics, have been derived from global asymptotic analysis. They continue to find useful astrophysical applications but have important limitations, including instabilities on various scales. The reformulation of these theories using local representations allows a more flexible approach in which turbulent flows and additional physics can be incorporated. The gas dynamics of a warped Keplerian disc is an especially rich problem involving linear and nonlinear resonances of coupled oscillators. Both warped and eccentric discs are far from hydrostatic equilibrium and can involve extreme vertical oscillations that challenge computational methods and physical understanding.

John Papaloizou

DAMTP

Dynamics of thin planetary rings

Planetary rings and protoplanetary discs can become eccentric through interactions with orbiting satellites or non axisymmetric gravitational perturbations due to a central object. In this process an m=1 mode is excited for which apse alignment is maintained with differential precession balanced against the effects of pressure or particle collisions as appropriate. The operation of these processes is reviewed un the context of the epsilon ring of Uranus and the ring system of (10199) Chariklo

Cristobal Petrovich

Pontificia Universidad Católica de Chile

Disk-planets interactions in misaligned discs: consequences for planetary orbits

Protoplanetary discs can develop non-coplanar structures, shaping not only their observed morphologies, but possibly also the three-dimensional architectures of planetary orbits. In this talk, I describe some new results for the inclination evolution of protoplanetary discs subject to torques from embedded planets and the host star’s rotation-induced bulges, and study the conditions of the disc evolution that can induce departures from coplanarity in planetary orbits. I apply these results to two observed planet populations, short-period planets with large stellar obliquities and multi-transiting planets with long-period Jovians, thus allowing to place constraints on the late-time evolution of tilted protoplanetary discs.

Tsvi Piran

Hebrew University of Jerusalem

Distorted disks in Tidal Disruption Events

When a star is tidally disrupted by a supermassive black hole its bound debris are launched onto very eccentric orbits. It was generally assumed that the returning stream circularizes rapidly forming a regular compact accretion disk. However, theoretical considerations, numerical simulation as well as observational evidence suggest that typically this isn't the case. In most TDEs the stream debris maintain their high eccentricity forming an elliptical disk. I will review the different reasoning for this revised picture, the observational evidence supporting it, some implications and new results concerning the evolution of such disks. Other distorted disks arise when a TDE takes place in an AGN. In these cases the disruption continues as if the AGN disk doesn't exist. However, upon returning to the vicinity of the black hole the disk-stream interaction disrupts the inner part of the AGN disk resulting in a unique observational signature. In the second part of my talk I will present recent numerical simulations of this phenomena and explore some of the observational implications.

Daniel Price

Monash University

Rocking shows in broken circumbinary discs

Narrow lane shadows have been observed in scattered light observations of a number of protoplanetary discs, indicating a large relative misalignment between the inner and outer disc (up to 70-90 degrees). Previous numerical studies have shown that such structures are most likely caused by a massive hidden companion on an orbit that is inclined to the outer disc. Using three dimensional simulations with coupled hydrodynamics and Monte Carlo radiative transfer we consider the evolution of such shadows on long timescales. We show that the shadows cast by the misaligned inner disc move within a confined range of position angles on the outer disc - over time, these shadows appear to rock back and forth in azimuth as the inner disc precesses. We attribute this phenomenon to a geometric effect due to the inner disc precessing about a vector that is misaligned to the outer disc and place limits on when this behaviour will occur. We also examine the evolution of the temperature structure due to the shadows cast on the outer disc. Finally, we draw a comparison between our results and observations of variable shadows in the strongly misaligned disc J1604.

Enrico Ragusa

University of Leicester

Eccentric circumbinary discs: when "eccentric" means conventional

Binary systems - be they stars or black holes - surrounded by gaseous discs are ubiquitous in astrophysics. Such discs exchange angular momentum with the binary through tidal torques, altering both the disc structure and the binary orbit. In this context, it is well known that the interaction of the accretion disc with a sufficiently massive binary companion will result in the formation of a disc cavity and, in some cases, in a significant growth of the disc eccentricity driven by some eccentric

Lindblad resonances (ELRs). However, most details of the eccentricity evolution, such as the maximum eccentricity the disc can develop, the morphology of the cavity and the disc structures typically associated to eccentric discs, have not been fully characterised yet, in particular when massive binary companions are present (mass ratio $q>0.05$). In this talk I will present our most recent efforts in understanding the evolution of the orbital eccentricity of circumbinary discs. Starting from a large set of 3D SPH numerical simulations, I will discuss how beyond a certain mass threshold of the binary companion (mass ratio q~>0.1), all our simulations (disc and binary initially circular) appear to show a rapid, unstable transition to an eccentric disc configuration. During this transition (most likely caused the binary disc interaction at some ELRs), the cavity significantly increases its semi-major axis (up to 4 times the binary separation) while the disc eccentricity rapidly grows to a maximum value, which appears to be determined by two distinct quenching mechanisms for the eccentricity growth. Finally, I will discuss which observational features emerge as typical in these eccentric circumbinary discs and which information regarding the system can be constrained from observations. Indeed, the eccentric nature of disc orbits are expected not only to both produce non-axisymmetric overdensities (both traffic jams and orbiting features) and affect the gas kinematics (detectable with ALMA), but also to shape the accretion rate on the binary producing characteristic luminosity patterns (with possible applications to black hole binaries).

Giovanni Rosotti

Leiden University

Spirals in gas and dust

High-resolution observations of proto-planetary discs show that spirals arms are a common structure and they have been observed in different tracers, i.e. the midplane mm dust, the small micron dust grains in the disc atmosphere, and gas molecular emission lines, begging the question of what are the theoretical expectations for each of these tracers. Using 2D (vertically integrated) dusty numerical simulations, under the assumption that spirals are launched by planets, I will present a comprehensive study of how the spiral structure in the midplane dust is related to the structure in the gas. I will show that there is no significant difference in the spiral morphology. For what concerns the amplitude, as expected the spiral in the dust becomes weaker as the Stokes number increases; however, the difference is quite limited and only for Stokes number greater than unity the spiral amplitude in the dust is significantly lower than in the dust. I will then present a semi-analytical model of the dust dynamics in the spiral, showing that it reproduces very well the result of the numerical simulations; the dust density can be accurately predicted once the gas rotational velocity is known. This open interesting observational possibilities since the gas rotational velocity is now becoming accessible with ALMA. I will then present recent ALMA observations of the disc around the star HD100453, showing instead that, in this case, in the same object the spirals show a different morphology depending on the tracer. In particular, the spiral in mm dust is more tightly wound than the one in the micron dust, with the spiral in CO molecular emission being intermediate. I interpret this difference from the 2D theoretical predictions as a 3D effect, since the three tracers trace different heights above the midplane. I will confirm this intuition through 3D hydro-dynamical simulations and I will identify the vertical dependence of the disc temperature as the main reason for the change in morphology.

Kedron Silsbee

MPE

The effect of disk asymmetry on planet formation in binary systems

Much of the literature on planet formation in binary star systems focuses on the dynamical interactions between a perturbing star, and the planetesimals and planets which form. The disks in such systems are also perturbed by the companion star, exhibiting both eccentricity, and misalignment with the orbital plane of the binary. The gravitational perturbations from the disk on the forming planets can be dominant over the perturbations from the companion star. I will discuss the effect of these perturbed disks on the formation and migration of planets in these systems. I will focus on two issues: the disruption of planetesimals in these disks due to their high collision velocities, and the migration and eccentricity excitation of circumbinary planets. In both cases, it is found that the details of the disk structure are a deciding factor in the outcome.

Sasha Tchekhovskoy

Northwestern

Simulations of tilted black hole accretion flows

In this talk, I will focus on tilted black hole accretion in which the midplanes of the black hole and its accretion disk are misaligned. Such misalignment naturally emerges since the gas at large distances is unaware of the direction of black hole spin. I will discuss how the tilt affects the ability of the accretion system to produce jets and outflows, in a wide range of astrophysical contexts, such as X-ray binaries, active galactic nuclei, and tidal disruptions, over a wide range of luminosity and disk thickness.

Jean Teyssandier

University of Namur

A Simplified Model for the Secular Dynamics of Eccentric Discs and Applications to Planet-Disc Interactions

In this talk I will present a simplified model that we developed for studying the long-term evolution of giant planets in protoplanetary discs. The model accounts for the eccentricity evolution of the planets and the dynamics of eccentric discs under the influences of secular planet-disc interactions and internal disc pressure, self-gravity and viscosity. I will review how we constructed this model from a linear theory of eccentric discs, and then discuss several applications of the model regarding long-term planet-disc interactions.

Philippe Thebault

Paris Observatory

Perturbed debris discs

Debris discs have been identified around a large fraction of main sequence stars through the mid-IR excess due to the emission of circumstellar dust grains. This dust is believed to be produced by the collisional grinding of much larger (and usually undetectable) parent bodies, typically kilometre-sized planetesimals or even larger Ceres or Moon-sized objects. An ever increasing fraction of debris discs have also been imaged, at wavelengths ranging from the optical to the millimetre. Interestingly, these resolved images almost always display pronounced spatial features, which can be of a great variety: axisymmetric or eccentric narrow rings, single or double-armed spirals, vertical distorsions and tilts, 2-sided asymmetries, arcs and clumps, etc. Understanding the origin of these spatial structures has been one of the main objectives of debris disc modelling for the past 3 decades. The most commonly investigated scenarios invoke the perturbing effect of (visible or hidden) planetary objects or stellar companions, but alternative explanations, such as violent and stochastic disruptive events have also been proposed, notably to explain bright clumps and « blobs ». Numerically investigating these different scenarios is a great challenge, mainly because it requires to study the coupled effect of fragment-producing collisions, dynamical perturbations and stellar wind or radiation. The latter processes, in particular, which are strongly size-dependent and can place small grains on highly eccentric or even unbound orbits, can greatly complexify the study of perturbed discs, and might explain why some of them display different morphologies depending on the wavelengths at which they are imaged.

Scott Tremaine

Institute for Advanced Study, University of Toronto

Lopsided galactic nuclei

The centres of most galaxies contain massive black holes surrounded by dense star clusters ("galactic nuclei"). Lopsided nuclei are likely to be common since the nucleus of the nearest large neighbour galaxy, M31, is lopsided. Lopsided nuclei can arise naturally through resonant relaxation, which drives a robust phase transition from a spherical thermal equilibrium to a lopsided equilibrium. The rate of transient events such as tidal disruptions is expected to be much higher in the lopsided phase.

Nienke van der Marel

Victoria

On the diversity of observed asymmetries and spiral arms in protoplanetary disks

Many bright protoplanetary disks show a range of asymmetries and rings in the millimeter dust continuum, thought to be caused by dust trapping in pressure bumps. Asymmetric dust traps have been linked to both vortices and horseshoes, caused by planetary and (sub)stellar companions, respectively. I will discuss how the asymmetric degree might be linked to the local gas surface density, based on a recent analysis of a demographic study of asymmetric and axisymmetric disks.

This relation provides a natural explanation for the diversity in asymmetric structures, and predicts that asymmetric structures in the gas may be much more common than previously thought. Second, I will present an overview of the limits on companion masses in gapped disks, which could help to distinguish between the vortex and horseshoe scenario. Some of the asymmetric millimeter features might be connected to the spiral arms detected in scattered light and 12CO images as well. I will discuss the relation between the observed spiral arms and the properties of the star and the companion, as suggested by current demographic studies.

Christopher White

Princeton University

Observable Consequences of Warps and Twists in Supermassive Black Hole Accretion Disks,

When the angular momentum of infalling matter is misaligned with respect to the spin of a black hole, differential torques can lead to a warped and twisted disk containing a pair of standing shocks. We report on the systematic trends seen by varying spin and tilt angle in thick disk simulations, noting that heating and angular momentum transport can be dominated by the effects of tilt. We then examine how such systems would appear different from aligned, planar accretion disks in the context of Event Horizon Telescope observations of M87 and Sgr A*.

J.J. Zanazzi

Canadian Institute for Theoretical Astrophysics

Eccentric Tidal Disruption Event Disks around Supermassive Black Holes: Dynamics and Thermal Emission

After the Tidal Disruption Event (TDE) of a star around a SuperMassive Black Hole (SMBH), an accretion disk rapidly forms from the stellar debris on highly elliptical trajectories. If the newly formed accretion disk remains eccentric with a radial extent much larger than the tidal radius, hydrodynamic simulations and order-of-magnitude arguments suggest many optical TDE candidate effective temperatures, blackbody emission radii, and bolometric luminocities can be explained by thermal emission from the TDE disk. Using a secular theory for a hydrodynamical disk with non-linear eccentric disturbances mediated by pressure, we study the dynamics and thermal emission from highly-eccentric disks formed after TDEs. We calculate the properties of uniformly precessing apsidally-aligned non-linear eccentric modes, and find slowly-precessing coherent eccentric modes exist for feasible models of newly-formed TDE disks, even under the influence of general-relativistic apsidal precession from the SMBH. Taking into account the vertical structure of an accretion disk on a highly eccentric orbit, we find the thermal emission from eccentric TDE disks can explain the effective temperatures, blackbody emission radii, and bolometric luminocities of many optical TDE candidates. Our work lends support to theories which argue optical TDE emission is powered by energy liberated during the circularization process, rather than accretion of material onto the SMBH.

Zhaohuan Zhu

University of Nevada Las Vegas

Spirals in Protoplanetary Discs

Spirals have been found both observationally and theoretically in a wide range of disc systems, from circumplanetary discs to galactic discs. In this talk, I will summarize some recent studies on spirals, focusing on protoplanetary disc systems. Observationally, spirals have been observed by both near-IR and sub-mm observations. Some spirals are associated with companions while some do not show such association. Recent gas kinematic observations can even reveal the velocity perturbations induced by the spirals. Theoretically, spirals have been studied in detail with both gas and dust components, and even with more complete thermodynamics being included. Combining both observations and theories can give us great insights on the formation mechanisms of spirals.

Poster Abstracts

Hossam Aly

Centre de Recherche Astrophysique de Lyon (CRAL)

Traffic jams, spirals, and dust pile-ups in inclined circumbinary discs

Binary stars exert torques on inclined circumbinary discs, leading to precession, warps, and (either co-planar or polar) alignment. While the effects of binary-induced precession on gas discs have been investigated thoroughly, I will report recent findings obtained from SPH simulations of the evolution of gas+dust discs subject to binary torque. I will concentrate on the behaviour of weakly coupled dust grains (Stokes number > 10). In this regime, gas and dust undergo different precession profiles, and the interaction between them leads to the formation of prominent dust spirals and density enhancement.

Giulia Ballabio

Queen Mary University of London

HD143006: circumbinary planet or misaligned disc?

Misalignments within protoplanetary discs are now commonly observed, and features such as shadows in scattered light images indicate departure from a co-planar geometry. VLT/SPHERE observations of the disc around HD143006 show a large-scale asymmetry, and two narrow dark lanes which are indicative of shadowing. ALMA observations also reveal the presence of rings and gaps in the disc, along with a bright arc at large radii. We present new hydrodynamic simulations of HD143006, and show that a configuration with both a strongly inclined binary and an outer planetary companion is the most plausible to explain the observed morphological features. We compute synthetic observations from our simulations, and successfully reproduce both the narrow shadows and the brightness asymmetry seen in IR scattered light. Additionally, we reproduce the large dust observed in the mm continuum, due to a 10 Jupiter mass planet detected in the CO kinematics. Our simulations also show the formation of a circumplanetary disc, which is misaligned with respect to the outer disc. The narrow shadows cast by the inner disc and the planet-induced "kink" in the disc kinematics are both expected to move on a time-scale of ~5-10 years, presenting a potentially observable test of our model. If confirmed, HD143006 would be the first known example of a circumbinary planet on a strongly misaligned orbit.

Deepika Bollimpalli

Max-Planck Institute for Astrophysics

Dancing Discs: Lense-Thirring precession of truncated discs and their inference to Type-C QPOs

Many accreting black holes and neutron stars exhibit rapid variability in their X-ray light curves termed quasi-periodic oscillations (QPOs). The most common are the low-frequency (< 10 Hz), Type-

C QPOs typically observed during the low/hard state and are thought to originate from the Lense-Thirring precession of a hot, geometrically thick accretion flow that is misaligned with respect to the black hole spin axis. However, it is not yet clear how the coupling between the outer geometrically thin disc and the inner hot flow may influence the precession, and this has not been accounted for in any of the currently existing models. To address this, we perform GRMHD simulations of a truncated disc with the inner hot flow misaligned with the spin axis of the black hole. Our results suggest that the inner hot flow precesses irrespective of the presence of the outer thin disc. We also noted that the misalignment excites variability in the inner hot flow, most likely c-modes, which are otherwise absent in the discs aligned with the black hole.

Yixian Chen

Tsinghua University

Streamlines in Tidally Distorted Disks

We propose a new method that solves the streamlines in 2D thin Circumbinary discs and Circumstellar discs in binary systems efficiently, whether around circular or eccentric binaries. The method uses the property of Fourier collocation points to represent derivatives of a periodic function, and does not involve any integral of motion. In disks with zero pressure, the method quickly gives out accurate Restricted Three Body orbits consistent with classical heuristic approach. We can also include gas pressure in this model from a Lagrangian perspective, and approximate stable gas streamlines in discs with non-negligible pressure.

Nicolás Cuello

IPAG/CNRS, Grenoble, France

Warped discs in multiple stellar systems

Protoplanetary discs within multiple stellar systems are heavily perturbed due to both gravitational and radiative effects. Circumbinary discs (CBDs) and discs affected by stellar encounters (a.k.a. flybys) are of particular interest since these are now directly imaged with modern telescopes (ALMA, SPHERE, VLA). These observations cover a broad range of wavelengths and can be directly compared to hydrodynamical and theoretical models. Here, by means of 3D SPH simulations, we explore gas and dust dynamics in highly misaligned CBDs with respect to the binary plane (e.g. HD 142527, HD 100453, AB Aur) and in systems where a flyby is suspected (e.g. AS 205, UX Tau, FU Ori). Remarkably, the disc morphology (e.g. warps, non-coplanar spirals, illumination asymmetries) provides strong constraints on the perturberâ€™s orbit. These results help to interpret recent observations but, more importantly, show that stellar multiplicity deeply affects disc formation and evolution around young stellar objects. Finally, we discuss the profound implications of stellar multiplicity on the resulting (misaligned) planetary architectures.

Sven De Rijcke

Ghent University, Belgium

Linear stability analysis of collisionless and collisional disks

Using the linearized Boltzmann equation, we show how grooves carved in the phase space of a collisionless disc can trigger the vigorous growth of two-armed spiral eigenmodes (De Rijcke et al. 2019a). Such grooves result from the self-induced dynamics of a disc subject to finite-N shot noise, as swing-amplified noise patterns push stars towards lower angular momentum orbits at their inner Lindblad radius. Thus, it is possible for an isolated, linearly stable stellar disc to spontaneously become linearly unstable via the self-induced formation of phase-space grooves through finite-N dynamics. These results may help explain the growth and maintenance of spiral patterns in real disc galaxies. We show how this linear stability analysis can be extended by taking into account gravitational softening (De Rijcke et al. 2019b), which eases the comparison with N-body/hydrodynamics simulations, and be made more realistic and widely applicable by including the gravitational coupling of the collisionless component to an embedded gaseous disk (De Rijcke, in prep.).

Hongping Deng

DAMTP, University of Cambridge

Parametric instability in a free-evolving warped protoplanetary disc

Warped accretion discs of low viscosity are prone to hydrodynamic instability due to parametric resonance of inertial waves as confirmed by local simulations. Global simulations of warped discs, using either smoothed particle hydrodynamics or grid-based codes, are ubiquitous but no such instability has been seen. Here, we utilize a hybrid Godunov-type Lagrangian method to study parametric instability in global simulations of warped Keplerian discs at unprecedentedly high resolution (up to 120 million particles). In the global simulations, the propagation of the warp is well described by the linear bending-wave equations before the instability sets in. The ensuing turbulence, captured for the first time in a global simulation, damps relative orbital inclinations and leads to a decrease in the angular momentum deficit. As a result, the warp undergoes significant damping within one bending-wave crossing time. Observed protoplanetary disc warps are likely maintained by companions or aftermath of disc breaking.

Sergei Dyda

University of Cambridge

MHD Simulations of Misaligned Black Hole Accretion Discs

A possible explanation of high frequency QPO's is a radiatively hot accretion flow precessing due to the Lense-Thirring (LT) effect. A key physical question is how magnetic stresses allow angular momentum to flow in the disc and hence alter the LT, test particle, assumption. We use magnetohydrodynamic simulations to study the evolution of misaligned discs. We compare results for inviscid and viscous alpha discs using our grid based methods and to previous simulations of viscous discs using smooth particle hydrodynamics which observe solid body precession and at high misalignment angles disc breaking. We then compare results of viscous discs where viscosity is driven self-consistently via the MRI and characterize the importance of moving away from the thin-disc, isotropic alpha-disc viscosity to adequately model precessing disc systems.

Callum Fairbairn

Astrophysical Fluid Dynamics and Non-Linear Dynamics Group - DAMTP - Cambridge

Dynamics of Radially Finite Axisymmetric Rings

Recent observations using ALMA have revealed a range of axisymmetric rings and gap structures in protoplanetary disks around young stars. Furthermore, theoretical and computational work suggests that warped disks can also break up into independently tilted rings. This motivates my work which investigates a novel semi-analytical approach for studying the subsequent axisymmetric tori oscillations in thick, ideal-fluid rings. These global modes are interesting since they exhibit the radially finite analogue of local oscillations present in extended warped disks. Such structures have also been used to explain the high frequency quasi-periodic oscillations around accreting black holes. In my work, I use a shearing box model and allow for compressible, linear flow fields. This provides sufficient freedom for a rich collection of breathing and tilting modes which exist for small perturbations from equilibrium configurations. This is extended to the fully non-linear regime where the dynamical behaviour is computed by numerically solving a coupled set of non-linear ODEs, using either a Eulerian or Lagrangian formalism. The results are consistent with those found using a full hydrodynamic solver such as PLUTO.

Amith Govind

Forschungszentrum Jülich

Effect of close stellar flybys in low-mass clusters.

Recent observations of many protoplanetary discs with spiral arms in young low-mass clusters have challenged theoretical models. A pattern analysis of some spiral arms indicate close flybys as the most probable cause. Hence this requires a rethink of the influence of flybys on protoplanetary discs in low-mass clusters. In this work we study the impact of flybys on protoplanetary discs in young low mass clusters, wherein we built on the observational fact that in the solar neighbourhood, low-mass clusters have a smaller extent than high-mass clusters. Hence, low-mass clusters can have mean and central density comparable to high-mass clusters. We use NBODY6++ to perform simulations of stellar dynamics using the observed cluster mass-radius relations. We find that low-mass clusters can affect discs sizes just as much as, if not more than, high-mass clusters. We even find a significant fraction of small discs (< 10 au) in low-mass clusters. The primary conclusion of this study is that close flybys cannot be neglected in low-mass clusters. We also provide few testable predictions, one of them being that 10%–15% of discs in low-mass clusters will be truncated by flybys to less than 30 au with a sharp outer edge.

Jane Huang

University of Michigan

Irregular Spiral Structures Traced by CO Emission around the RU Lup and GM Aur Protoplanetary Disks

While complex millimeter continuum structures have now been mapped by ALMA for a number of protoplanetary disks, comparatively few of these have been accompanied by deep gas observations. This poster presents recent CO observations of RU Lup and GM Aur, obtained as part of DSHARP follow-up and as part of the MAPS ALMA Large Program, respectively. In contrast to their largely axisymmetric, multi-ringed millimeter continuum, the CO emission of both of these disks reveal large-scale, non-Keplerian spiral arms. The irregular kinematics and morphological resemblance to some younger embedded systems suggest that RU Lup's and GM Aur's spirals could arise due to continuing interactions with their environments.

Haochang Jiang

Tsinghua University

Survival of ALMA Rings in the Absence of Pressure Maxima

Recent ALMA observations have revealed that a large fraction of protoplanetary discs contain bright rings at (sub)millimeter wavelengths. Dust trapping induced by pressure maxima in the gas disc is a popular explanation for these rings. However, it is unclear whether such pressure bumps can survive for evolutionary time-scales of the disc. In this work, we investigate an alternative scenario, which involves only dust-gas interactions in a smooth gas disc. We postulate that ALMA rings are a manifestation of a dense, clumpy mid-plane that is actively forming planetesimals. The clumpy medium itself hardly experiences radial drift, but clumps lose mass by disintegration and vertical transport and planetesimal formation. Starting from a seed ring, we numerically solve the transport equations to investigate the ring's survival. In general, rings move outward, due to diffusion of the clump component. Without pressure support, rings leak material at rates $\sim 40\ M_\oplus\ \mathrm{Myr}^{-1}$ and in order for rings to survive, they must feed from an external mass reservoir of pebbles. In the case where the pebble size is constant in the disk, a cycle between ring formation and dispersion emerges. Rings produce large quantities of planetesimals, which could be material for planet formation and explain the massive budget inferred debris disc. Mock images of ALMA observations compare well to the rings of Elias 24 and AS 209 from DSHARP's sample.

Jiaru Li

Cornell University

Ring Formation in Protoplanetary Discs Driven by an Eccentric Instability

Protoplanetary discs may spontaneously generate multiple concentric gas rings without an embedded planet through an eccentric cooling instability. Using both linear theory and non-linear hydrodynamics simulations, we show that various background states may trap a slowly precessing, one-armed spiral mode that can become unstable when the disc cools. The spiral naturally evolves into ellipses as the instability saturates. The angular momentum required to excite this spiral comes at the expense of non-uniform mass transport that generically results in multiple rings. Our fiducial long-term hydrodynamics simulation exhibits four long-lived, axisymmetric gas rings. We verify the instability evolution and ring formation mechanism from first principles with our linear theory, which shows remarkable agreement with the simulation results.

Min-Kai Lin

ASIAA

Vortex survival in 3D self-gravitating protoplanetary disks

Large-scale vortices may be inherent to protoplanetary disks, which can play key roles in interpreting observations and in facilitating planetesimal formation. However, vortices are susceptible to 3D, destructive `elliptic instabilities' that may threaten their survival. It is therefore important to understand how vortices can be sustained in realistic, 3D protoplanetary disks. We present shearing box simulations of 3D vortex evolution in self-gravitating disks, showing that moderate self-gravity can help vortices persist against elliptic instabilities. We interpret this result as a 'gravito-elliptic feedback', where the vortex spins down due to the elliptic instability, which favors gravitational contraction that tends to spin up the vortex. The result from this feedback cycle is a quasi-steady 3D vortex with a turbulent core that survives for ~1000 orbits. Our simulations suggest that large-scale vortices survive more easily, and hence are more likely observed, at large radii in protoplanetary disks.

Feng Long

CfA

Revealing the binary and its misaligned circumbinary disk of V892 Tau

The evolution of circumstellar disks in a multiple stellar system can be significantly affected by the binary and disk interactions, which have direct consequences on the formation and survival of the associated planetary system. We present high resolution millimeter continuum and CO line observations for the circumbinary disk around V892 Tau to constrain the stellar and disk properties. We constrain the total stellar mass based on our models of the Keplerian-dominated gas disk rotation, and provide an updated view of the binary orbit. The radial extension of the circumbinary disk, its asymmetric dust ring, and the presence of a disk warp revealed from CO observations could all be explained by the interaction between the eccentric binary and the circumbinary disk, which we assume were formed with non-zero mutual inclination. Our analyses demonstrate the promising usage of V892 Tau as an excellent benchmark system to study the details of binary--disk interactions.

Cristiano Longarini

Università degli Studi di Milano

Dynamical dust traps in non-planar circumbinary discs

In many cases the result of star forming process is a binary (or multiple) system. In particular, if the collapse is forming a binary system, three discs can be formed: two around the stars (circumprimary and circumsecundary) and a larger disc surrounding both the stars, called circumbinary. Because of the chaotic nature of star formation, the disc morphology hardly remains flat, and we expect to see at least some circumbinary discs misaligned to the binary orbital plane. In this poster I present an analytical and numerical study of dust traps in misaligned circumbinary discs. I found that pile-ups of dust may be induced not only by pressure maxima, as the usual dust traps, but also by a dynamical mechanism. Indeed, the difference of speed between gas and dust induced by the precession motions balances the physical one, due to pressure gradient, in two locations. In these positions, the drag force does not act, thus dust particles, migrating inward because of radial drift, piles up and forms two dust rings. I analytically tackled this mechanism and I performed numerical simulations using the SPH code PHANTOM. I found an overall agreement between the results of the simulations and the analytical expectations. In addition, I apply the above model to explain the peculiar dusty structures of the system GW Orionis through this phenomenon. This mechanism is significant in the context of planetary formation in binary stellar systems because these traps could foster the dust coagulation and the formation of planetesimals.

Joshua Lovell

University of Cambridge

What caused q1 Eri's Asymmetric Debris Disc?

Since 2007 it has been known that q1 Eri hosts an asymmetric debris disc from scattered light imaging, however with recent high resolution ALMA imaging, we investigate in further detail the nature and origin of these asymmetries.

Elliot Lynch

University of Cambridge

Propagation of Nonlinear Eccentric Waves in Discs around Black Holes

Excitation of trapped inertial waves, via interaction with an eccentric disc, has been proposed as an explanation for the High-Frequency Quasiperiodic Oscillations (HFQPOs) observed in the emission of black hole X-ray binaries. Previous work has shown that in linear theory the eccentric wave can be highly oscillatory in the inner region of the disc. We extend existing work to include the effects of nonlinear eccentricity and disc twist using an averaged Lagrangian method. We also consider the excitation and damping of these eccentric waves.

Farzana Meru

University of Warwick

Distorted self-gravitating discs caused by fragments

Recent advances in observations of protoplanetary discs have not only provided images of discs with spiral structures, but have also stressed the importance of self-gravitating discs. By performing 3D hydrodynamical simulations of protoplanetary discs, we present the mechanisms by which spiral structures can form in observed discs. It is also well-known that under the right conditions, self-gravitating discs may fragment to form planets or brown dwarfs. We perform simulations to show that the interaction between a fragment and its parent disc can trigger further fragmentation to occur. We show that the resulting interactions between multiple fragments and the disc can significantly distort the disc resulting in large scale non-axisymmetric features, as seen in recent observations of a fragmenting protoplanetary disc.

Tim Pearce

AIU, Jena

Fomalhaut b could be massive and sculpting the narrow, eccentric debris disc, if in mean-motion resonance with it

When it comes to debris disc systems with interesting dynamics, few are more intriguing than Fomalhaut. The system contains a narrow, eccentric debris disc, where the origin of this eccentricity is unknown. The system also hosts the enigmatic, is-it-a-planet-or-is-it-something-else object Fomalhaut b, which is on a highly-eccentric orbit that potentially passes through the disc. Such an extreme orbital configuration could be expected to disrupt the neat debris ring, and for this reason it is often argued that, whatever Fomalhaut b is, it cannot have significant mass. However, if Fomalhaut b is coplanar with the disc then the two show a high degree of orbital alignment, which may be hinting at an ongoing dynamical interaction. By re-analysing the possible orbits of Fomalhaut b and conducting detailed dynamical analyses, we show for the first time that the observed debris ring could actually be in mean-motion resonance with a coplanar, planetary-mass Fomalhaut b. Despite Fomalhaut b being disc-crossing in this configuration, we show that resonant debris would be stable for the stellar lifetime and occupy narrow, eccentric orbits similar to the observed disc. Furthermore, whilst these large resonant bodies would have a clumpy distribution, we show that dust released in collisions would form a narrow, relatively smooth ring similar to observations. More generally, the narrow, low-eccentricity dust rings that we simulate may not have been expected to exist in the presence of a highly-eccentric perturber, but we find that they manifest themselves across a broad region of parameter space. We conclude that if Fomalhaut b has a mass between those of Earth and Jupiter then, far from removing the observed debris ring, it could actually be sculpting it through a resonant interaction. The argument that Fomalhaut b cannot have significant mass without disrupting the observed disc is therefore not necessarily correct.

Anna Penzlin

University Tübingen

What circumbinary disc tell us about general disc parameters

Circumbinary disc show large inner cavities as well in observation as in simulations. By understanding the behavior of the cavity, we may be able to better understand the system as a whole. By varying the scale height and viscosity we can change the resulting size and eccentricity of the inner cavity. When applying this parameters to observations we may be able in the future to constrain the viscosity needed to create observed cavities, implying a good general guess on the viscosity values of protoplanetary discs.

Jeremy Rath

Northwestern University

Steady-State Solutions for Eccentric Planets in Low Mass Disks

Accretion disks have been observed around both stars and black holes, but there are still many unanswered questions regarding their structure and interaction with an embedded object. It is unclear what is the physical origin of the cavities observed in transitional disks---are the cavities caused by a single planet? Likewise, under what circumstances do accretion disks shrink or expand the orbits of their binaries? We study systems containing an accretion disk and an eccentric planet (or binary companion) that have reached viscous steady state (VSS) using both numerical simulations and analytic theory. VSS is characterized by a pileup exterior to the planet and an accretion rate that is spatially constant in the disk. From the VSS solutions for the planet/disk system, we obtain the gap size and pileup strength of the disk and the migration rate of the planet.

Sahl Rowther

University of Warwick

Suppressing Signatures of Gravitational Instabilities in Self-Gravitating Protoplanetary Discs

In their youth, protoplanetary discs are expected to be massive and self-gravitating, which results in non-axisymmetric spiral structures. However recent observations of young protoplanetary discs with ALMA have revealed that most discs with large-scale spiral structures are rarely observed in the midplane. Instead, axisymmetric discs with some also having ring & gap structures are more commonly observed. Here we study the impact that physical processes such as planet-disc interactions and warps (two mechanisms that are commonly thought to occur in these young discs) have on the disc structure. We demonstrate that they are able to alter the disc's evolution, suppressing the large-scale spiral structure of self-gravitating protoplanetary discs -- potentially resolving this discrepancy between observations and theoretical predictions.

Taeho Ryu

The Johns Hopkins University

The Impact of Shocks on the Vertical Structure of Eccentric Disks

Despite eccentric disks' observational importance, the evolution of their vertical structure is poorly understood. In this paper, we investigate this problem by using 1-D hydrodynamics simulations of individual gas columns assumed to be mutually non-interacting. We find that gravitational pumping caused by the time-dependence of vertical gravity generically creates shocks near pericenter; these shocks affect larger fractions of the disk mass for larger eccentricity and/or disk aspect ratio. Energy dissipated in the shocks is removed from the orbital energy; because the kinetic energy per unit mass in vertical motion near pericenter can be large compared to the net orbital energy, the heat given to gas can unbind some of it. This could be a potentially important energy dissipation and mass loss mechanism of eccentric disks.

Antranik Sefilian

DAMTP, University of Cambridge

Potential softening and eccentricity dynamics in nearly Keplerian discs

In many astrophysical problems involving discs orbiting a dominant central mass, the gravitational potential of the disc plays an important dynamical role. The dynamics driven by discs can usually be studied using secular approximation. This is often done using softened gravity to avoid singularities arising in the calculation of the orbit-averaged potential - disturbing function - of a razor-thin disc using Laplace-Lagrange theory. We explore the performance of several softening formalisms proposed in the literature in reproducing the expected eccentricity dynamics in the disc potential. We identify softening models that, in the limit of zero softening, give results converging to the expected behaviour exactly, approximately or not converging at all. Our results suggest that numerical treatments of the secular disc dynamics - i.e. representing the disc as a collection of N gravitationally interacting softened rings - are rather demanding, requiring a fine numerical sampling. We find that this requirement is further aggravated for discs with sharps edges, such as planetary/debris rings.

Antranik Sefilian

DAMTP, University of Cambridge

Formation of gaps in self-gravitating debris discs

Debris discs are ubiquitous around main sequence stars. Recent high-resolution observations of debris discs by ALMA and direct imaging have revealed a rich variety of structures such as gaps, warps, spirals, etc. Modelling of debris disc morphology is often focused on studying the dynamical imprints of planets, somewhat analogous to the studies of the Asteroid and Kuiper belts. However, studies of planet-debris disc interactions normally treat the disc as a collection of massless particles; ignoring the gravitational effect of the disc itself. In this talk I will present results indicating that self-gravity of debris discs could be important for producing some of the observed disc structures.

Specifically, I will present a novel pathway to sculpting gaps - i.e. double-ringed structures - in broad debris discs that is naturally mediated by the disc gravity. Application of these results for explaining observations will be discussed at length, with a particular focus on the double-ringed disc around HD 107146.

Dimitri Veras

University of Warwick

The lifetimes of planetary debris discs around white dwarfs

The lifetime of a planetary disc that orbits a white dwarf represents a crucial input parameter into evolutionary models of that system. Here we apply a purely analytical formalism to estimate lifetimes of the debris phase of these discs, before they are ground down into dust or are subject to sublimation from the white dwarf. We compute maximum lifetimes for three different types of white dwarf discs, formed from (i) radiative YORP break-up of exo-asteroids along the giant branch phases at 2–100 au, (ii) radiation-less spin-up disruption of these minor planets at ~1.5–4.5R$\odot$, and (iii) tidal disruption of minor or major planets within about 1.3 R$\odot$. We display these maximum lifetimes as a function of disc mass and extent, constituent planetesimal properties, and representative orbital excitations of eccentricity and inclination. We find that YORP discs with masses of up to 10^(24) kg live long enough to provide a reservoir of surviving cm-sized pebbles and m- to km-sized boulders that can be perturbed intact to white dwarfs with cooling ages of up to 10 Gyr. Debris discs formed from the spin or tidal disruption of these minor planets or major planets can survive in a steady state for up to, respectively, 1 or 0.01 Myr, although most tidal discs would leave a steady state within about 1 yr. Our results illustrate that dust-less planetesimal transit detections are plausible, and would provide particularly robust evolutionary constraints. Our formalism can easily be adapted to individual systems and future discoveries.

End of abstracts