A Closer Look at the Erosion Barrier in Protoplanetary Discs

Marco Agolzer

The first step of planet formation in the core accretion paradigm involves the pair-wise growth of (sub)microscopic dust grains through a process known as dust coagulation. Although efficient for microscopic grains, there are several barriers preventing the resulting mm- and cm-sized "pebbles" from growing. Current simulations of dust coagulation highlight mostly the growth barriers associated with fragmentation and radial drift. However, it is thought that a third process, dubbed "erosion", can also play a major role. Erosion is the mass-loss of larger particles resulting from frequent high-velocity collisions of small impactors onto larger dust grains (m_target/m_impactor > 10).

We investigate the erosion barrier through simulations using the open-source code DustPy. While the standard implementation of DustPy includes high mass ratio collisions, the model utilised for erosion assumes projectiles excavate at most exactly the equivalent of their own mass during impact. Recent experimental work has shown that erosion can be much more dramatic, with erosion efficiencies as large as ~10-100, suggesting erosion could halt (local) dust coagulation before any other barriers are met.

We will present a results of a suite of DustPy simulations of protoplanetary discs exploring different values of erosion efficiency, the viscosity parameter and fragmentation velocity, shedding light on how and when erosion can impact the (a) maximum particle size, and (b) shape of the dust size distribution. We discuss our findings in the context of existing grain size constraints from dust continuum observations and speculate on the impact of erosion on planetesimal formation through the streaming instability.

WARWICK
THE UNIVERSITY OF WARWICK

UKI Discs

Poster Abstracts

Binding environments of precursors to complex organic molecules in protoplanetary disks: a computational study

Aneesa Ahmad

The presence of complex organic molecules (in the form of gas-phase methanol) in protoplanetary disks have finally been revealed around young stars in observations with ALMA (the Atacama Large Millimeter/submillimeter Array); methanol is found to be rotationally cold and likely arising from non-thermal desorption from the cold icy reservoir in the disk midplane. The confirmation of methanol in protoplanetary disks has revealed the presence of a complex organic ice reservoir in disk midplanes for the first time. This reservoir may be processed to form molecules of higher complexity, the rates of which depend on the binding energies and binding environments of key radicals under the conditions in disk midplanes. We have modelled amorphous solid water and methanol ices, as well as mixed water-methanol ices at several temperatures; 10K, 20K, 50K, and 70K, yielding a range a range of interstellar ices, from which we have extracted amorphous clusters. In this research talk, we explain the motivation behind this work, and show the results of some simulations of the binding of methanol, water and their associated radicals with our interstellar ice clusters. This research has been carried out using molecular dynamics simulations performed using the GROMACS software package, DFT calculations were performed using the Gaussian16 software package and binding energies were computed using the binding energy evaluation platform (BEEP) at the mpwb1k-d3bj_def2-tzvp level of theory.

WARWICK
THE UNIVERSITY OF WARWICK

UKI Discs

Poster Abstracts

Free-floating planets ejected from massive self-gravitating discs

Aleksandra Ćalović

Microlensing surveys have significantly increased the number of proposed free-floating planets (FFPs). In order to better understand the origin of these FFPs, we have run simulations of self-gravitating discs with a number of massive planets up to brown dwarf mass objects. The interaction of the massive object with disc leads to inwards migration of the massive object, which in turn causes planet-planet orbit crossing. This causes the planets to be ejected from the system, where they would join the population of FFPs. We get an average of 60% of planets from the system being ejected throughout our simulations. The 'surviving' planets have an average final eccentricity of around 0.2 after all the ejections have taken place. The velocity dispersion of the ejected planets is around (1.4 ± 0.9) km/s; using this we can make predictions of the velocity distributions we would expect to see from a population of FFPs ejected via planet-planet scattering, using observed velocity distributions of FFPs we could allow us to differentiate the formation mechanism of the ejected planets.

WARWICK
THE UNIVERSITY OF WARWICK

UKI Discs

Poster Abstracts

Following the long-term evolution of dusty fragments formed via gravitational instability

Maggie Celeste

Hydrodynamics simulations are a valuable tool to understand planet formation via gravitational instability. However, gravitational fragmentation in protoplanetary discs is generally computationally expensive to simulate; timesteps typically become increasingly short as the simulation progresses and fragments collapse. AREPO is a public hybrid hydrodynamics code that features adaptive spatial resolution, allowing simulations to follow fragmentation for a significantly longer period of time than is typically done in SPH. Because of the important role that dust transport plays in planet formation, we have added a multifluid dust module to AREPO, before using it to simulate fragmenting protoplanetary discs. We can use the dust:gas ratio as a proxy for volatile abundance of the resulting fragments, and are primarily concerned with the composition of those fragments that survive long-term. Fragments that are eventually disrupted are still of interest if they remain intact for a significant period of time and achieve high dust:gas ratios while they do persist, as they could present a site for rapid dust growth that would be pertinent to later planet formation mechanisms.

WARWICK
THE UNIVERSITY OF WARWICK

UKI Discs

Poster Abstracts

Hydrodynamical Simulations of Planet-Disk Interactions in PDS 70: Characterizing Gap, Spiral, and Vortex in the Disk.

Daniel Daza Valdebenito

The interaction of planets with the disk from which they form produces characteristic features visible in the thermal emission of the dust as observed by ALMA. However, in many cases we are left with the doubt whether the observed features are indeed the result of a present planet, or by a different hydrodynamical process. The system PDS70 is therefore special and highly important: it poses a unique testbed for this planet-disk interaction. As to date, it is the only disk where two giant protoplanets have been detected and confirmed. We use new insights from high-resolution, multifrequency observations in ALMA band 4, 7 and 9 to compare them to hydrodynamical simulations using FARGO3D and study the radiative transfer of the disk using RADMC-3D. We explore which are the conditions that allow to reproduce the large gap, the spiral broadened ring and the prominent vortex in the disk. Comparing the observations with the hydrodynamical simulations we study the role of planetary migration, turbulence and disk temperature.

Poster Abstracts

Dust Polarization Up Close and Personal in a Planet-Forming Disk

Rachel Harrison

We present high-resolution ALMA observations of polarized emission in the protoplanetary disk HD 97048 at 870 μm. A previous study of gas kinematics in HD 97048 found evidence of a Jupiter-mass planet located between two dust rings. Constraining the dust grain properties in this disk therefore gives us insight into dust evolution at the time of planet formation. We observed polarized emission consistent with scattering (i.e., the scattering of thermal emission from dust grains by other dust grains) in the disk. The polarization fraction and angle are correlated with the disk's ring and gap substructure, and these changes are well explained by variations in optical depth and the direction of radiation anisotropy within the disk. We model the expected polarization in this disk for dust grain populations with varying sizes and porosities, and discuss the implications for dust evolution in this planet-forming disk.

Poster Abstracts

A trail of dust from a young embedded brown dwarf in the outskirts of the Orion Nebular Cluster

Thomas Haworth

JWST NIRCam has revealed an embedded brown dwarf that is associated with an extremely long, narrow dark trail in the outskirts of the Orion Nebula. A very strong sensitivity of the scattering opacity to maximum grain size at JWST wavelengths means that this dark trail can be explained purely in terms of a maximum grain size enhancement in the dust. However, the question remains what gives rise to the trail of larger dust. We explore various possibilities, with the two most promising being mass loss of circum-brown-dwarf material by a weak external photoevaporative wind or a Bondi-Hoyle-Lyttleton accretion wake.

WARWICK
THE UNIVERSITY OF WARWICK

UKI Discs

Poster Abstracts

North PHASE observation of the young cluster Tr37

Ferdinand Hollauf

The North-PHASE Legacy Survey is using the T80 telescope from the Javalambre Observatory (Spain) to study variability in several young clusters in the northern hemisphere. It produces time-resolved observations that enable us to 'use time to map space', identifying young variable stars and the processes that cause their variability, such as stellar spots, accretion variations, and occultations by circumstellar material. I will present the initial results for the cluster Tr37, which will be the subject of my PhD, having started in January 2024.

Poster Abstracts

Understanding CO Depletion in Wind-Driven Protoplanetary Discs

Zuzanna Jonczyk

Recent ALMA observations have revealed a significant decrease in the gas-phase CO abundance within protoplanetary discs, with CO abundances depleted by up to two orders of magnitude relative to the interstellar medium. One plausible explanation for this depletion is CO sequestration in ice on the surfaces of large grains. An essential ingredient of this mechanism is the diffusion of CO from the upper layers of the disc to the midplane, where temperatures are low enough for CO to freeze out. The efficiency of CO sequestration is therefore sensitive to the strength of turbulence in the disc, requiring turbulent alpha parameters of around 10^-3 to produce sufficient depletion on Myr timescales. However, ALMA has revealed that mm-sized grains form thin dust layers in protoplanetary disc mid-planes, indicating that turbulence may be much weaker than this. MHD winds are therefore currently considered important in the outer regions of protoplanetary discs, and their effects on disc composition are yet to be understood. I will present the results of new work investigating the impact of MHD-driven winds on the depletion of CO. I use state-of-the-art cuDisc simulations to model dust-gas dynamics, grain growth, and freeze-out, investigating the impact of these processes on gas-phase CO abundance to understand how CO depletion in wind-driven discs compares with viscous discs.

Poster Abstracts

Debris disc catalogue - I. Herschel PACS photometry

Minjae Kim

The goal of the current study is to present the debris disc catalogue of Herschel Space Observatory observing programmes using the Photodetector Array Camera Spectrometer (PACS), together with the main statistics and scientific results that can be extracted.

Poster Abstracts

Simulations of Gravitational Instability in Irradiated Protoplanetary Discs

Cat Leedham

Fragmentation due to gravitational instability (GI) in protoplanetary discs can cause large spiral structures and is a potential formation mechanism for giant planets. This mechanism is relevant at large radii where the disc is cold enough that irradiation from the central star will be significant to the disc's thermal evolution. Irradiation is expected to increase the Toomre Q parameter away from the level for marginal instability (Q~1-2) and stabilise the disc against GI. However, using local 2D hydrodynamic simulations, we investigate the difference between two methods of implementing irradiation - heating per unit mass and per unit area of the disc. In the former case, no instability is present once the level of irradiation becomes the dominant source of heating. However, in the latter case, we find that GI persists and fragmentation can occur even in irradiated discs with high values of Q. These results highlight the importance of proper implementation of irradiation in numerical simulations and open a wider range of disc parameter space that may be susceptible to GI.

Poster Abstracts

First ALMA observations of the HD 105211 debris disc: A warm dust component close to a gigayear-old star

Qiong Liu

In this work, we investigate the structure of the disc surrounding the nearby F2V star HD 105211, which has a warm excess and a potential asymmetry in the cold belt. We applied the CASA pipeline to obtain the ALMA 1.3 mm continuum images. Then we constructed the SED and performed MCMC simulations to fit a model to the ALMA visibility data. To characterise the disc asymmetry, we analysed the ALMA images of two individual observation blocks and compared them to the previous Herschel images. Our modelling reveals that the disc is a narrow ring (23.6+-4.6 au) with low eccentricity positioned at a distance of 133.7+-1.6 au from the central star, which differs from the broad disc (100+-20 au) starting at an inner edge of 87+-2.5 au, inferred from the Herschel images. We used a two-temperature model to fit the infrared SED and used the ALMA detection to constrain the warm component to a nearly pure blackbody model. The relatively low ratio of actual radius to blackbody radius of the HD105211 debris disc indicates that this system is depleted in small grains, which could indicate that it is dynamically cold. The excess emission from the stellar position suggests that there should be a warm mm-sized dust component close to the star, for which we suggest two possible origins: in situ asteroid belt or comet delivery.

Poster Abstracts

Modelling the Dust substructures in the AGE-PRO sample

Lilian Luo

Determining gas mass within protoplanetary disks is crucial for understanding their evolution into planetary systems. AGE-PRO, a recent ALMA Large Program, aims to advance our knowledge of disk evolution by utilising observations of CO and N2H+ across 30 disks spanning three distinct star-forming regions with ages ranging from 0.1 to 10 Myr. Traditionally, gas mass estimates have relied on thermochemical models assuming homogeneous distributions of gas and dust. However, emerging multi-wavelength observations reveal significant substructures within these disks, particularly in dust emission, which may influence these estimates.

Poster Abstracts

Testing the shock bow model with the variations in exocometary absorptions of high ionized species as Al III observed by HST around Beta Pic.

Cristina Madurga Favieres

Exocomets are small icy bodies composed of rocks and dust that orbit around stars. As they approach their host stars, they sublimate and form a bright envelope of gas and dust around them: the coma. As the material flows into space, two tails are left behind, one of dust and one of ions. Their composition and dynamical distribution are revealed by spectroscopic analysis of the exocomets tails and can be more understandable by comparing them with the comets in our solar system.

The largest amount of exocometary activity observed so far is around Beta Pic, a young and bright star. It is represented by absorption features in the far-UV lines, such as Al III, C III and Si IV. This is particularly surprising as the star is unable to ionize such species by itself. One possible explanation is that, if exocomets approach the star within a few stellar radii, a compressed shock surface front is formed and collisions within it may induce the ionization. In order to confirm the exocometary shock model, new observations from the Hubble Space Telescope have been proposed. By measuring the blue and redshifted variations of the absorption lines, we get the acceleration exocomets suffer towards and away from the star, and therefore, estimate their distance to it. We are currently analysing the first observations to test the model, which proposes that the Al III line should be detected closer than 5 R*, and to find similarities with known comet shocks in the solar system.

Poster Abstracts

The Effect of Eccentricity on the Accretion Rate onto Newly Formed Planets in Protoplanetary Discs

Aaron Mills

When planets form and evolve in protoplanetary discs, they accrete material from the disc. This material first flows onto a circumplanetary disc, before falling onto the planet. We investigate the significance of the protoplanet's orbital eccentricity on the variability of the accretion rates, and how this affects the planet's evolution. Using the SPH code Phantom, we simulate the evolution of a young planet in a protoplanetary disc. We vary the eccentricity of the planet and measure the accretion rate onto the circumplanetary disc and the planet itself. We find that these accretion rates for a planet on an eccentric orbit may vary by an order of magnitude during one period. Accretion rates which vary to this extent could influence the formation of satellites around the planet.

Poster Abstracts

Dust rings in warped protoplanetary discs

Rebecca Nealon

Most protoplanterary discs are born in chaotic environments that result in multiple accretion episodes and encounters. We thus expect most planet forming discs to experience some kind of misalignment or warp during their evolution. Recent work has shown that the dust in warped discs forms into rings with characteristic structures specifically as a result of how the warp affects the gas and dust orbits (the Warp Induced Dust Instability or WInDI). However this work was limited to disc parameters that did not resemble a protoplanetary disc. I will present a thorough investigation of WInDI in the context of protoplanetary discs and it's relevance to planet formation.

WARWICK
THE UNIVERSITY OF WARWICK

UKI Discs

Poster Abstracts

A Search for Transiting Exocomets in TESS Sectors 1-26

Azib Norazman

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 is 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 detection is around 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. The updated search algorithm consists of finding the largest transiting events in all TESS lightcurves, determining their shape and amplitude from model fitting, and vetting the remaining candidates to remove false-positive detections. We present the exocomet candidates detected with this search method.

Poster Abstracts

Dust Entrainment in 1D Externally Photo-Evaporated Models

Sébastien Paine

The environment in which circumstellar discs evolve plays a crucial role in their evolution, and the formation of planets. In stellar clusters, nearby large stars will irradiate gas and dust: heating the disc and entraining planet-forming solids. An important, but under-studied aspect of this is what sizes of dust get entrained in the disc wind. This affects the amount and position of planet-forming solids, as well as dust shielding the disc from UV radiation. We have developed a particle solver to track the entrainment of dust in multi-dimensional simulations of photo-evaporating discs. We validate an existing analytic estimate in 1D by Facchini et al. (2016) and propose a modified analytic solution, taking into account the orbiting dust's angular momentum. Accounting for the centrifugal force leads to larger dust sizes being entrained than previously predicted. This has implications for the structure of gas mass loss from the disc, and for the observational characteristics of proplyds in the infrared.

Poster Abstracts

Understanding the shapes of circumbinary discs

Anna Penzlin

Stars are mostly to form with siblings, in binary or multiple configurations. The separation of stars vary from spectroscopy sub-au but to orders of magnitude to 50au, while still part a common circumbinary disc. And the shape and features of these disc reflect the stellar and the disc properties in a non-linear way. In this work, we show how the circumbinary disc shape changes due to properties like viscosity, eccentricity, cooling and binary eccentricity through 2d hydrodynamic simulations of a large parameter space. In general cavities around the binaries can reach large eccentricities, however, this depend on the disc viscosity and the thermodynamic conditions in the disc.

Poster Abstracts

Dust Dynamics in Protoplanetary Discs after Stellar Flybys

Vasu Prasad

Star forming regions are chaotic environments, and we expect that dynamical interactions between protostars, such as flybys, are very common. These interactions can shape the protoplanetary discs around young stars, for example by truncating or distorting them. In this work, we investigate dust dynamics during flybys, focusing our attention on how the solid particle distribution changes during and after a dynamical encounter.

We present results from 3D smoothed particle hydrodynamics (SPH) simulations of a protoplanetary disc undergoing a parabolic flyby from an unbound perturbing star. We vary the periastron distance of the flyby, the mass of the perturbing star and the inclination of the orbit and study the evolution of the gas and dust dynamics in the circumprimary disc during and after the flyby using the SPH code PHANTOM. We focus particularly on the spiral arms induced during the flyby and the increase in dust density in these spirals. Our ultimate aim is to study whether or not the spirals persist for long enough and have a high enough dust density to be favourable locations for planetesimal formation by concentrating solid particles in dust traps.

Poster Abstracts

Disc Evolution and planet formation in stellar cluster environment

Lin Qiao

Most stars form in dense stellar clusters that contain massive stars. Massive stars in these clusters emit large amounts of UV radiation that "externally photoevaporates" the protoplanetary discs which leads to truncated discs with lower masses. Radiation from massive stars also leads to asymmetric heating of discs inducing dynamical instabilities, and all this effects could impact disc evolution and subsequent planet formation (Qiao et al. 2022, Qiao et al.2023). Understanding the role of environments can therefore be important for explaining the observed diversity of exoplanet systems. I will present about my research in studying the impacts of the external radiation from the discs' birth environment on

1. Disc evolution with disc viscous evolution model coupled with realistic stellar cluster and feedback simulation
2. Planetary system formation via pebble accretion with N-body planet formation code
3. Disc dynamical instabilities induced via external heating via hydrodynamical simulations

WARWICK
THE UNIVERSITY OF WARWICK

UKI Discs

Poster Abstracts

Circumplanetary Winds: A hydrodynamical study of planet formation during planetesimal accretion

Danilo Sepúlveda

Accretion processes onto compact objects, including black holes and young stars, are systematically associated with jets and outflows across a range of scales. This phenomenon has been well-documented over a wide range of mass scales; however, there is a notable absence of literature exploring the possibility of planetary outflows. More recent observations with ALMA, have revealed disturbances in the rotation of protoplanetary disks, resulting in what are known as ""Doopler-Flips."" One notable example is the disk around HD100546. Our hypothesis is that these disturbances are caused by planetary outflows. The aim of our study is to investigate the potential impact of planetary winds on disk evolution through the use of hydrodynamical simulations. In particular, the focus is on how such outflows affect planetary accretion, whether they result in larger protoplanetary gaps, and if these winds can explain the observed kinematic properties of disks.

WARWICK
THE UNIVERSITY OF WARWICK

UKI Discs

Poster Abstracts

"Using time to map space" with the North-PHASE Legacy Survey

Aurora Sicilia-Aguilar

North-PHASE is a 5-year (2023-2028) Legacy Survey at the Javalambre Observatory and stands for ""Periodicity, Hot spots, Accretion Stability and Early evolution in young stellar clusters in the northern hemisphere"". Using time-resolved, multi-cadence, multiwavelength, large field data, it unveils structures and processes in young stars at the relevant scales for inner planet formation beyond what can be directly resolved, while also studying the connection between stars and disks, their formation history, and their clusters, independently of astrometry. North-PHASE is unique 'using time to map space', covering thousands YSO for a statistical study of their variability and the physical processes to which it is linked.

I will present the results from the first year of observations, following 6 young clusters with time-resolved data for 4.5k+ stars down to 0.3 Msun. By using 6 photometry filters (SDSS griz, Halpha, u-band) we can distinguish the complex processes that affect YSO variability (e.g. accretion, extinction by circumstellar matter, hot and cold spots). The observed timescales allow us to connect these processes to physical structures in the YSO and their disks, allowing us to map stellar properties as well as to distinguish variability types for statistically-significant samples of YSO, thus peering into the physics of magnetospheric accretion, inner disk evolution, and stellar activity. The large FoV covers entire clusters, which enables us to study not only YSO evolution vs age and stellar mass, but also the role of cluster environment and initial conditions in stars, disks, and their outcomes, independently of the astrometry.

Poster Abstracts

How super-Earths migrate in low-turbulence radiative disks

Alexandros Ziampras

Low-mass planets migrate in the type-I regime. In the inviscid limit, the contrast between the vortensity trapped inside the planet's corotating region and the background disk leads to a dynamical corotation torque, which is thought to slow down inward migration. We investigate the effect of radiative cooling on low-mass planet migration using inviscid radiation hydrodynamical simulations. We find that for intermediate cooling timescales (β~0.1-100), cooling induces a baroclinic forcing on material U-turning near the planet, resulting in vortensity growth in the corotating region. For longer cooling timescales, the disk buoyancy response has a similar effect. Both mechanisms in turn weaken the dynamical corotation torque, are active for a substantial radial extent of the disk ($R \sim 0.1$–50 au), and lead to significantly faster, sustained inward migration. We finally make a note on current developments on planet migration in low-turbulence disks and how radiative effects change this picture.