The inner disk of young stars: accretion, ejection, and planet formation

The close-in sub-stellar companion triggering periodic accretion bursts to the magnetic class I protostar V347 Aur *(O)*

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V347 Aur is a transitioning object between class I and class II, showing a flat-spectrum SED, illuminating bright nebulosities, and associated with a Herbig-Haro object. It is therefore a very young star (<1 Myr) that will evolve as a classical T Tauri star. V347 Aur is also a strong photometric variable showing periodic bursts with a period of about 160 d. The spectro-photometric analysis of Dahm & Hillenbrand (2020) has demonstrated that the bursts are most likely due to accretion of matter from the circumstellar disk. They conclude that a close companion, triggering accretion bursts, is the most likely hypothesis, while not being able to detect it. Thanks to the large programs SLS and SPICE, we have densely monitored V347 Aur with SPIRou for 4 years in order to study the evolution of its magnetic strength and topology as a function of its photometric variation. We obtain two important results: (i) we detect the radial velocity variations of the protostar with a period similar to the photometric bursts period, caused by a companion at the planet/brown-dwarf mass limit ; (ii) we detect a clear change of the stellar magnetic field before and after the accretion bursts suggesting that stellar magnetic fields may be affected by strong accretion bursts. In this contribution we propose to present the observations, the results, and discuss their implication on our understanding on close-in massive-planets/brown-dwarf formation, on star-planet-disk interaction, as well as on the protostellar magnetic field evolution and its impact on star/planet/disk evolution.

The inner disk of young stars: accretion, ejection, and planet formation

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The accretion/ejection connection in young low mass stars *(I)*

Silvia Alencar (1) (presenting author)

1 Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

The dynamical star-disk interaction is mediated by the stellar magnetic field that truncates the inner disk at a few stellar radii (~0.1 au) from the star, and controls accretion and outflows processes in this region. I will review observational evidences of the accretion/ejection connection in young low mass systems, discussing the results of multiwavelength campaigns in the time domain compared to MHD simulations of the star-disk interaction.

Young clusters' rotation period distribution explained by self-consistent evolution models with accretion and rotation : The importance of structural changes *(O)*

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The angular momentum evolution of the star-planet-disc system is quite complex and still poorly understood despite a lot of effort and some recent breakthrough. For instance, observations indicate that stars with a disc tend to rotate more slowly even though they accrete angular momentum, to the point that during the first 10 Myr, young low-mass stars do not seem to spin-up while they are expected to contract. In an attempt to answer this question, I will present state-of-the-art stellar evolution models with accretion which include a self-consistent treatment of angular momentum evolution derived from dynamical multi-D MHD simulations. We explore the observed range of several parameter, such as the accretion rate history, the final mass, the composition and the thermodynamics of the accreted material, as well as the large scale magnetic field strength of the central star. I will show that the observed spin rate distributions, the long-standing disc-locking problem, as well as other observed properties of very young stars can be explained by the complex interplay of the different processes. I will conclude on how the structural and kinematic changes of the star may affect planetary formation and the evolution of the inner-disc.

HM Lup: probing the inner disk structure of a Classical T Tauri Star using simultaneous spectro-photometric data *(P)*

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Young stellar objects are known to be variable, both photometrically and spectroscopically, over a broad range of wavelengths. Therefore, it is essential to study these objects using a multi-wavelength approach, by means of simultaneous observations in different spectral regions.
Such a possibility is now offered by coordinated spectroscopic campaigns such as ULLYSSES (HST) and PENELLOPE (VLT).
The target of our study, HM Lup, is one of the ULLYSSES and PENELLOPE targets with the best simultaneous spectroscopic coverage of the photometric TESS light curves and AAVSO BVRI observations.
The photometric behaviour indicates that the system belongs to the class of the quasi-periodic bursters. Optical spectra were taken in different phases of the main burst observed in the TESS photometry.
We investigated the accretion properties and the variability of HM Lup using the X-Shooter, HST/STIS and ESPRESSO spectra, finding evidence for an increase in the accretion rate during the burst.
HM Lup presents a rich emission line spectrum which, in addition to the usual emission lines observed in Classical T Tauri Stars, such as the Balmer series, Ca II H & K and He I, shows an unusual dominance of lines from permitted transitions of singly and doubly ionised metals, mostly Fe I and Fe II, a characteristic in common with the outburst spectra of EXors.
The different excitation potentials of the observed species and the differences in the overall profiles indicate the presence of a stratified environment, with multiple regions that contribute to the observed spectrum. The iron lines probe an outer region of the accretion flow that is excited during the outburst.
The variations in the emission profiles of the Balmer series suggest structural changes in the inner disk structure.

UV-driven Evolution and Chemistry of Protoplanetary Disks: Insights from HST's ULLYSES Program *(O)*

Nicole Arulanantham (1) (presenting author)

1 Space Telescope Science Institute, Baltimore, United States

Beginning in December 2019, approximately 70 T Tauri stars were observed at UV wavelengths through the Hubble UV Legacy Library of Young Stars as Essential Standards Director's Discretionary program (ULLYSES). These publicly available spectra provide critical observational constraints on UV irradiation of protoplanetary disks, a key driver of the gas phase chemistry that sets the initial conditions for planet formation. We use the HST data and radiative transfer models to reproduce the LyA emission seen by surface layers of the gas disks, which typically makes up the largest component of the total integrated UV flux. The model LyA flux available to photodissociate molecules like H2O, HCN, and CH3CN within disks with dust cavities and gaps varies by two orders of magnitude, and we explore how the spread might translate to observable chemical differences. We also investigate whether ultraviolet emission lines from UV-fluorescent H2 can be used to break the degeneracy between disk flaring and UV irradiation of the gas in models of sub-mm CN emission. This work is critical for interpreting molecular features in T Tauri systems observed with ALMA and JWST, demonstrating how UV radiation propagates from the accretion shocks to the outer disks.

The inner disk of young stars: accretion, ejection, and planet formation

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The structure of molecular inner disks and winds from infrared spectroscopy *(I)*

Andrea Banzatti (1) (presenting author)

1 Texas State University, San Marcos, TX, United States

[Invited review] I will review the status of infrared spectroscopy of molecules in planet-forming (Class II) disks from 20 years of data from ground- and space-based observatories, including what we are now learning from the very first JWST spectra. I will discuss multiple science angles from studying different kinematic components that trace gas in inner disks and winds at 0.01-10 au: their physical and chemical structure, kinematics, excitation, and evolution. I will briefly present spexodisks.com, an online database of 1000+ infrared spectra from 7 spectrographs that is now available to the community in support of observing and modeling efforts worldwide. I will outline how the synergy of multiple molecular and atomic tracers is paving the way to a comprehensive view of gas evolution in inner planet-forming disks, and a beautiful coherent picture that is emerging.

The inner disk of young stars: accretion, ejection, and planet formation

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Star-planets-disc interactions and the early orbital evolution of close-in planetary systems *(I)*

Clément Baruteau (1) (presenting author)

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Nearly half of the exoplanets confirmed so far orbit around their star in less than 10 days. Were they mostly grown in-situ? Did they form further out in their protoplanetary disc and migrated toward their star by disc-planet interactions? Were they entrained on to high-eccentricity orbits instead before being circularized by star-planet tidal interactions? This presentation will not solve these questions, but it will address them by reviewing how disc-planet and star-planet tidal interactions impact the orbital evolution of young planetary systems.

Infrared absorption of 23 meteorites from the Atacama Desert *(O)*

Grace Batalla Falcon (1) (presenting author), Lucas C. Cieza (1), Roberto Lavín (1), Bin Yang (1)

1 Universidad Diego Portales, Santiago, Chile

Dust particles are the dominant source of opacity at infrared and (sub)millimeter wavelengths. While accurate dust opacities are crucial for modeling protoplanetary disks properties, their estimation is highly uncertain in this regime: dust opacities values used in models are mostly extrapolations in wavelength and grain sizes. In order to resolve these caveats is crucial to dedicated laboratory efforts. To tackle this problem and to help the astronomical community to make the most of the revolutionary JWST and ALMA observations, we have established the UDP Cosmic Dust Laboratory, the first one of its kind in Chile and Latin-America. We have started operations working on infrared measurements of meteorites from the Atacama Desert, planning to extend our opacity measurements to the submillimeter regime.

Meteorites are the best analogs of the type of dust expected in protoplanetary disks, and the most accessible samples from the Earth to study in the laboratory. The semiarid to hyper arid climates of deserts allows preservation and accumulation of meteorites. Being the driest desert in the world, the Atacama Desert shows an exceptional meteorite concentration per km2 that has remained hyper-arid for several Myr and has preserved meteorites for a long time with a very low erosion rate and slow chemical weathering.

In this first study, I will present measurements of dust opacities of 23 meteorites, 3 carbonaceous and 20 ordinary chondrites (types H, L and LL) from the Atacama Desert. We correlated their infrared spectra (2-23 microns) with chemical composition and the grain size distribution (Batalla et al., to be submitted to Icarus). As part of this work, we have developed all the necessary procedures to prepare the samples, characterize their grain size distribution and measure the dust opacities. Measuring dust opacities in the laboratory is conceptually straightforward, performing transmission/absorption experiments in which a light source is transmitted across the sample before it reaches the detector, and we conducted it with a Bruker Vertex 80v spectrometer. For dust grains, a few mg of sample material is embedded in ~100 mg KBr that is transparent at IR wavelengths, following well-tested preparation techniques. The mass absorption coefficient k (cm2/g) is calculated using k = S/M ln(100/T), where S is the surface area of the pellet, M is the mass of sample in the pellet, T is the % transmission at a given wavelength. The mass absorption coefficient (MAC) can be used in radiative transfer modeling to be compared to astronomical data of protoplanetary disks, since the absorbance efficiency of a particle is equivalent to its emissivity in thermodynamic equilibrium.

Observational links between the inner and outer protoplanetary disk regions *(I)*

Myriam BENISTY (1) (presenting author)

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Observational links between the inner and outer protoplanetary disk regions

Recent observing campaigns have revealed a great diversity in exoplanetary systems whose origin is yet to be understood. How and when planets form, and how they evolve and interact with their birth environment, the protoplanetary disks, are major open questions. Protoplanetary disks evolve and dissipate rapidly while planets are forming, implying a direct feedback between the processes of planet formation and disk evolution. These mechanisms leave clear imprints on the disk structure that can be directly observed in the outer disk.

In the past few years, high-resolution observations of protoplanetary disks obtained in the infrared scattered light and in the millimeter regime have led to exquisite images and shown that small scale structures are ubiquitous in protoplanetary disks in both gas and dust tracers. I will present recent observational results on protoplanetary disks, that allow to probe the disk structure and the dynamics of solids and gas in the outer disk, with a special focus on results that establish a strong connection between the structure and physics of the inner and outer disk regions.

Optical line fluorescence as a diagnostic tool for probing the close environment of young stars

(P)

Claude Bertout (1) (presenting author)

1 CNRS, Paris, France

The fluorescent FeI emission observed in active T Tauri stars (TTSs) is one of the defining properties of this class of young stars (cf. Joy 1945), but it has not been studied in any kind of detail in recent years. I discuss the formation of the FeI 3969Å line, which shares the same upper level as the 4063Å and 4132Å enhanced lines and can be anomalously excited by either one of the nearby CaII H and H I Hepsilon transitions. I use a line formation code developed for the occasion, written in Python/NumPy and designed to handle spectral line interactions in a variety of situations. I consider several velocity fields and envelope properties and find that FeI 3969Å fluorescent excitation occurs in all velocity fields considered, even at temperatures for which the iron atoms are mainly ionized, provided the gas density is high enough to make the exciting line at least partly optically thick. In particular, FeI line amplification appears stronger when driven by Hepsilon (rather than by CaII H), as occurs in an accretion flow, because the hydrogen line is usually optically thicker than the calcium line for envelope properties typical of TTSs. Blend profiles also differ considerably in different velocity fields, which may lead to observational constraints. Fluorescence affects not only the FeI line, but also the other lines of the blend, depending on the velocity field. Both FeI 3969Å and Hepsilon are affected by fluorescence in an accelerating outflow, while both FeI 3969Å and CaII H are amplified in an accretion flow. All three lines are affected in non-monotonic flows, which lead to complex distant radiative interactions. While the current investigation is limited by both assumptions of spherical symmetry and lte initial atomic populations, it makes it clear that studies of line fluorescent emission can be a valuable tool for probing quantitatively the inner envelopes of young stellar objects.

The inner disk of young stars: accretion, ejection, and planet formation

Imaging the closest environement of young stars with GRAVITY *(P)*

Youcef Bouarour (1) (presenting author)

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The study of the innermost regions of protoplanetary disks is now possible with long baseline Optical/NIR interferometry since it allows to probe these regions at sub astronomical units resolution. Although, this technique is widely used at radio wavelengths, interferometric imaging at optical and near-infrared wavelengths is very challenging. Therefore very few images at NIR wavelengths are available. In this talk, I will present some of the few reconstructed images of young stellar objects in the K-band using the ESO VLTI instrument GRAVITY. The images allow us to recover morphological details of the innermost region around the young Herbig Ae star HD58647 and high-mass YSO IRAS13481-6124. Furthermore, thanks to the high spectral resolution of GRAVITY, the region emitting the HI Br ? line has also been spatially resolved. This has allowed us to image reconstruct for the first time the line emitting region around HD58647, helping us to constrain the origin of the Br ? line around YSOs.

Young Inner Planet Detection *(I)*

Luke Bouma (1) (presenting author)

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Many processes in exoplanet evolution happen either when the disk is present, or in the first few million years after it disperses. These processes are hard to observe because most exoplanets are billions of years old. I will review the current state of the art in young inner planet detection, with a focus on what it can teach us about planet evolution. I will describe some of the core advances that have already been made through application of the transit and radial velocity methods, and I will also point out the ways in which star and star cluster characterization have also played a central role. I'll close by outlining areas in which existing and upcoming data are expected to yield near-term progress.

The inner disk of young stars: accretion, ejection, and planet formation

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The inner disk structure of FU Orionis *(O)*

Guillaume Bourdarot (1) (presenting author), Jean-Philippe Berger (2), Geoffroy Lesur (2), Karine Perraut (2), Fabien Malbet (2)

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2 Institut de Planétologie et d'Astrophysique de Grenoble, Saint Martin d'Hères, France

The FU Orionis phenomenon is an important stage of TTauri formation, however the instability mechanism at the origin of its outburst is still poorly understood. Here, we present the first spatially resolved monitoring of FU Orionis itslef, where we measure the evolution of the size of the outbursting region over time by combining more than 20 years of near-infrarared interferometric data. We compared this spatio-temporal structure of the disk with magneto-hydrodynamical simulations of the outburst. This comparison provides strong evidence for a gravitational instability scenario triggered in a magnetically dead zone in FU Orionis. Finally, this study will be complemented by the analysis of the CO absorption lines, that we spatially resolved with VLTI/GRAVITY. Together, these observations shed new light on the structure of the disk and on the instability mechanism at the origin of FUors.

2D and 3D analysis of the corotation region and torque for low-mass planets *(P)*

Joshua Brown (1) (presenting author), Gordon Ogilvie (1)

1 DAMTP, Cambridge, United Kingdom

The non-linear corotation torque on low-mass planets provides important opposition to the Lindblad, or wave torque, which seeks to drive inward migration of planets; moreover it places a bound on the timescale on which low-mass planets may persist near the inner disc. We present 2 and 3 dimensional asymptotic mathematical descriptions of the steady non-linear coorbital flow, and directly calculate the corotation torque on the planet when small gradients in potential vorticity and entropy are imposed over the corotation region. We find the 3D horseshoe region width, which is well-defined for low-mass planets, and present a softening prescription for the gravitational potential of the planet consistent with 3D theory.

Ionization rates by magnetic reconnection events in inner T Tauri discs

(P)

Valentin Brunn (1) (presenting author), Alexandre Marcowith (1), Christophe Sauty (2), Marco Padovani (4), Christian Rab (5)

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3 LUPM, Montpellier, France
4 INAF, Florence, Italy
5 University Observatory Munich, Munich, Germany

Magnetic reconnection is one of the major particle acceleration processes in space and astrophysical plasmas. Low-energy supra-thermal particles produced in magnetic reconnection events are a source of ionization for circumstellar discs, influencing their chemical, thermal and dynamical evolution. The aim of this work is to study how energetic particles propagate in the circumstellar disc of a T Tauri star and how they affect the ionization rate of the disc plasma. We have computed ionization rates by energetic particles considering the physical properties of the flares as observed by the Chandra satellite for a sample of sources in the Orion Nebula (COUP). These results are obtained for a disc which chemical equilibrium is calculated by the chemistry code PRODIMO. In a stationary configuration, the ionization rates generated by the particles produced by the magnetic reconnection event are, in the near-flare environment, at least 3 orders of magnitude higher than the ionization rate produced by the stellar sources. We further present results for a more realistic time-dependent model. This model is based on a Monte-Carlo analysis performed by sampling luminosity, duration and position of the flares and waiting time between two flares. These samples are extracted from observations of young stars and the Sun. Our analysis produces spatial and temporal amplitude averaged maps of inner disc ionization rates that can be compared with observations.

The inner disk of young stars: accretion, ejection, and planet formation

The accretion-ejection-rotation connection in T Tauri stars: a statistical study

(P)

Pauline Mc Ginnis (2) (presenting author), Sylvie Cabrit (1), Catherine Dougados (3)

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While it is well established that high-velocity jets from classical TTS are accretion-driven, their main origin and launching mechanism remains a matter of debate, with three possible contributors (see eg. Ferreira et al. 2006 for a review): an accretion-driven stellar wind (ADSW), an X-wind (or ReX wind) launched from the disk truncation radius, and a more extended magneto-centrifugal wind from the inner disk (D-wind). To help discriminate between these options, we present a statistical study of the accretion-ejection-rotation connection in CTTS using the [OI]6300 line as a tracer of high-velocity jets, UV excess or Halpha as a tracer of accretion, and photometric variability period as a tracer of stellar rotation. Our core sample is made of 30 CTTS in NGC 2264 with jets detected in [OI] and accurate rotational periods from the COROT satellite, and is complemented by similar published data for jet-driving CTTS in Taurus-Auriga, Lupus and Chameleon. Particular care is taken to correct jet speeds for line-of-sight projection, with system inclinations inferred from measured periods and vsini (or if they are unavailable, by resolved disk maps). The jet properties are correlated with accretion and stellar parameters, and confronted to specific predictions for each of the three proposed theoretical scenarios for the jet origin. The results outline the necessity of improving the accuracy of jet mass-fluxes (by combining spatially resolved observations with shock models) to obtain a definitive answer on the key issue of the jet origin in CTTS.

The inner disk of young stars: accretion, ejection, and planet formation

Investigating the link between winds/outflows, disk substructures, and protoplanets *(O)*

Justyn Campbell-White (1) (presenting author), Carlo Manara (1), Myriam Benisty (2)

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2 Institute of Planetology and Astrophysics of Grenoble, Grenoble, France

Protoplanetary disks are now routinely observed around young stars but the planets they produce remain elusive to detect. So far, we have only one confirmed detection of protoplanets in the disk of PDS 70, with some tentative results (e.g. AB Aur). Yet disk structures are found almost ubiquitously across the sample of resolved disks. We are investigating the potential relationship between inner disk winds and outflows (traced by optical emission lines, such as [OI]), and the presence and type of disk substructures. We aim to determine whether or not the various substructures are the direct results of protoplanet formation.

We will present new results from recent and archival observations of PDS 70. In order to investigate such connections between winds, substructures, and planets, we turn to the one system where we have certainly detected the planets. We have carefully applied established techniques to the high-resolution spectra to reveal previously unseen forbidden emission profiles. These results suggest a weak wind originating from the inner disk. We compare these results and measurements of the mass accretion rate and disk properties to those of other weakly accreting young stars and those with transition disks.

We are also carrying out this investigation for the PENELLOPE/ULLYSES sample of ~80 young stars. This complements existing surveys of such winds/outflows, whilst allowing for further exploration of the relation to disk substructures, towards a more complete statistical survey.

The inner disk of young stars: accretion, ejection, and planet formation

The Solar System's Record of Inner Disk Processes *(I)*

Fred Ciesla (1) (presenting author)

1 University of Chicago, Chicago, United States

The inner solar nebula likely saw the highest temperatures throughout our protoplanetary disk, with temperatures, particularly early on its evolution, reaching well-above those needed to vaporize dust. This means that much of what was inherited from interstellar medium in this region was destroyed and then reassembled into new minerals and compounds that were then incorporated into the planetesimals that formed in the inner Solar System. While few, if any, planetesimals from this region remain today, we are still able to get insights into the processes that shaped this region of the solar nebula by examining asteroids and comets in our solar System today. Despite these bodies largely forming multiple astronomical units from the young Sun, they contain materials that are thought to have originated much closer in and then were transported outwards to be accreted by planetesimals that formed much further away. In addition, the diversity of asteroid types, meteorite parent bodies, and cometary properties points to a range of environmental conditions present and physical processes that operated at different times and locations throughout the solar nebula, allowing us to extrapolate to what may have been found close to the young Sun. Thus, we have both direct and indirect evidence that we can use to gain insights into the evolution of the inner regions of our protoplanetary disk.

In this review, I will discuss how meteorites and cometary samples, as well as the bulk properties of the terrestrial planets, can be used to gain insight into the chemical and physical processes that operated in the inner solar nebula. I will highlight what we believe we know about this region along with outstanding questions that we still have yet to answer. I will discuss how we can leverage this information to better understand the processes that operated or are operating in the inner region of protoplanetary disks around other stars and vice versa.

The inner disk of young stars: accretion, ejection, and planet formation

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Constraining disk evolution by measuring the mass accretion rates of Classical T Tauri stars.

(O)

Rik Claes (1) (presenting author), Carlo Manara (1), Justyn Campbell-White (1), Antonio Frasca (2), Beate Stelzer (3), Joshua Lovell (4), Juan Manuel Alcala (2)

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4 University of Cambridge, Cambridge, United Kingdom

Studying the accretion process is key to understanding protoplanetary disk evolution and therefore planet formation. In particular, the spread in mass accretion rate as a function of disk mass is a way to test and constrain disk evolution models. To do so it is necessary to assess the impact of variability on these relations. Here I will discuss the impact of variability through the lens of a Classical T Tauri stars (CTTS) with an extreme accretion variability that was discovered in thanks to the PENELLOPE sample: XX Cha.
The mass accretion rates obtained for the entire PENELLOPE sample and its implications on disk evolution models and the inner disk will also be discussed.
These results were obtained using the most reliable way for determining the accretion properties of Classical T Tauri stars (CTTS). This method consists of fitting observed spectra with a UV excess accretion slab model, reddening law and a template representing the stellar photosphere. Improving the statistical determination of the best fit and providing posterior probabilities on the determined mass accretion rates allows us to better understand the observed spread and make it a stronger constraint on disk evolution models. Therefore, I will also discuss my work towards providing the community a user-friendly tool for the derivation of stellar and accretion properties using this method.
The photospheres of YSOs are strongly modified by this chromospheric activity and have a different surface gravity compared to field dwarfs. Because of this, spectra of non-accreting weak lined T Tauri stars (WTTS) need to be used to represent the photosphere. Part of this work, therefore, consisted of extending the grid of available WTTS templates, extracting the relevant features, and interpolating them. Doing so allows us to perform a computationally efficient MCMC analysis that enables us to analyse a large sample of CTTS.

The inner disk of young stars: accretion, ejection, and planet formation

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Peering into the inner disk with near-infrared interferometry *(I)*

Claire Davies (1) (presenting author)

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Bright, relatively nearby young stellar objects (YSOs) permit the study of inner disc structure with infrared interferometers, the only technique with sufficient spatial resolution to discriminate between competing models of inner disk structure. In addition, current 4- and 6-telescope beam combiners are providing sufficient imaging fidelity to open up infrared interferometric studies to the time-domain, allowing us to study the evolution of disk structure on sub-au scales for the first time. In this review, I will provide an overview of recent studies of YSO disk structure from near-infrared beam combiners at the VLTI and CHARA, highlighting ensemble results from YSO surveys with PIONIER and GRAVITY as well as in-depth studies of individual YSOs with MIRC-X and MYSTIC.

JWST Observations of the H2 outflows in the Class I protostar DG Tau B: disk wind versus swept-up cavity ? *(P)*

Valentin Delabrosse (1) (presenting author), Catherine Dougados (1), Benoit Tabone (2), Sylvie Cabrit (3), Thomas P. Ray (4), Linda Podio (5), Alois de Valon (1), Lukasz Tychoniec (6), Melissa McClure (7)

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In the early stages of star formation, as long as accretion is active, spectacular bipolar gas ejections are always observed. They are split into two distinct components: high velocity and collimated jets and lower velocity and wider molecular outflows. The exact role played by jets and outflows in the evolution of protoplanetary disks and, in particular, how much mass and angular momentum they carry away from the system remain important unanswered questions.

Recent ALMA observations of the Class I DG Tau B system revealed a massive slow and rotating CO outflow, challenging the traditional interpretation of molecular outflows as swept-up material (de Valon et al. 2020, 2022). Instead these results indicate a possible origin in an MHD disk wind originating from the innermost parts of the disk (within a few AU), from regions where the MRI cannot be effective (dead zone). However, the interpretation of a swept-up cavity cannot be completely excluded. Critical constraints on the jet/outflow interaction are missing.

The Cycle 1 JWST programme (PI: Catherine Dougados) on DG Tau B, with combined NIRCAM, NIRSpec IFU and MIRI-MRS observations, aims to map the warm component of the outflow in the H2 lines, filling the gap between the hot axial jet and the cold CO outflow. The ALMA and JWST data are complemented by SINFONI/MUSE observations from the VLT. This unique multi-wavelength combination of observations will allow a comprehensive study of the mass loss in the DG Tau B system.

We present preliminary results from the NIRSpec IFU observations, providing constraints on the morphology and excitation conditions of both the H2 molecular outflow and the fast axial jet traced for e.g. in [Fe II].
Thanks to a very precise wavelength calibration of the SINFONI data, we study the kinematics of the H2 outflows and constrain their rotation.
These results are confronted to expectations from jet/wind driven cavity and disk wind models and give us important clues to understand the origin of protostellar outflows and their impact on protoplanetary systems.

The inner disk of young stars: accretion, ejection, and planet formation

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Emission line variability of young accreting 10-30MJup companions as diagnostics of ongoing accretion mechanisms. *(P)*

Dorian Demars (1) (presenting author), Mickael Bonnefoy (1), Catherine Dougados (1), Yuuhiko Aoyama (2,3,4), Thanawuth Thanathibodee (5,6), Gabriel-Dominique Marleau (7,8,9,10), Pascal Tremblin (11), Philippe Delorme (1), Paulina Palma-Bifani (12), Simon Petrus (13,14), Brendan Bowler (15), Gaël Chauvin (1,12), Anne-Marie Lagrange (1,16)

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Accretion processes on stars have been heavily studied in the past 20 years, however they are only now starting to be investigated on forming planets and low-mass brown dwarf companions. While current techniques do not permit the study of accretion processes on close-in planets, the advent of high-contrast imaging in the past decade allowed for detection of emission lines indicative of active accretion (Hα, Paβ, Brγ, ...) on a dozen of wide-orbit planetary-mass companions (PMCs, 5-30MJup). They provide a unique opportunity to study accretion processes at the very low mass end and the impact on planetary evolution. Line variability is common on accreting pre-main sequence stars. It has been fortuitously evidenced on a handful of PMCs, but never characterized in detail. Variability can help clarify the accretion mechanisms at play and revise current protoplanet detection strategies.

We present the results of a monitoring campaign of the Paschen Beta emission line (1.28µm) of three accreting 10-30MJup companions on wide orbits with the VLT/SINFONI integral field spectrograph. We discuss the line profiles and their variability in the more general context of accreting young stars and compare them with predictions of accretion models recently developed for planetary mass objects. Implications for the origin of the accretion process in these sources are discussed. We also derive atmospheric parameters (Teff, log g, C/O ratio, M/H) of each object from J-band spectra modeling using the latest grids of atmospheric models (ATMO).

(P) Poster / (I) Invited Talk / (O) Oral

Impact of circumstellar disc on planetary transit signatures in classical T Tauri stars *(P)*

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Pre-main sequence stars are expected to emit strong levels of XUV flux, on average a hundred times that of main sequence stars. A few planets have been detected transiting such stars (V1298Tau, K2-33, AU Mic). A planet placed in such an environment is likely to undergo strong hydrodynamic evaporation. Eventually, strong atmospheric absorption signatures are expected when such planets are seen in transit configuration. Over the past two decades, the measure of these signatures has led to the detection of various species in exoplanet atmospheres. Improvements in resolution and sensitivity however revealed the potential biases induced by the stellar lines locally occulted by the planet along its transit chord. For example, centre-to-limb variations and stellar rotation can easily impact the characterisation of transiting exoplanets atmospheres and sometimes lead to false detections. These effects are starting to be well constrained and the community is more and more taking them into consideration in their planetary transit models. However, an other contamination intervenes for very young stars such as classical T Tauri stars as they are surrounded by a circumstellar disc of gas and dust which potentially fall in the line of sight of the planetary transit. We study the impact of such a disc on the expected planetary atmospheric absorption signatures that could be observed. Using our simulations of planetary transits and adding the presence of a disc, we explore a series of relevant parameters such as e.g. the inclination of the line-of-sight, the dimensions of the disc or the inclination of the star's rotation axis. We wish to set up the range of detectability of transiting planets around very young stars still surrounded by their circumstellar disc.

The inner disk of young stars: accretion, ejection, and planet formation

AB Aur: a testbed for planet-disk interactions from sub-au to 200au scale *(O)*

Emmanuel Di Folco (1) (presenting author), Anthony Boccaletti (2), Sylvestre Lacour (2), Anne Dutrey (1), Thomas Collin-Dufresne (1), Arnaud Pierens (1), Eric Pantin (3)

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Observing disk structures is a powerful means to infer the presence of forming planets in disks around young stars. The weakness of emission from protoplanets with the additional extinction by dust grains makes their detection extremely challenging. AB Aurigae is one of very few nearby, young stars where compelling evidence of protoplanets has been reported. This includes the presence of two prominent spiral arms seen in emission from gas and small dust grains revealed by ALMA and SPHERE within the broad 120au cavity. In addition, three bright spots spread between 30au and 100au, which are possible sites of giant planet formation, were detected by SPHERE/VLT and CHARIS/Subaru.

We will report on second-epoch polarimetric observations with SPHERE, which confirm our initial findings and constrain the dynamics of the remarkable disk structures down to 0.1'' scale. Evidence of Keplerian rotation calls into question the exact link between spiral patterns and the suspected planets. New SPHERE/ZIMPOL measurements allow us to investigate the strength and shape of the claimed Halpha line detection at the location of the AB Aur b companion candidate, and to further search for accretion signatures throughout the cavity. VLTI/GRAVITY was also used to constrain the K-band spectrum of the innermost planet candidate. We jointly detected a prominent Br gamma emission line, an accretion tracer, towards the central star and resolved the inner circumstellar disk. All together, these new observations probe the young star's environment from sub-au out to 200au scales, and bring new clues to investigate planet-disk interactions and the connection between the inner and outer disk regions.

We complement this observational approach with hydrodynamical simulations of planet-disk interactions with a multi-fluid approach using the FARGO3D code. We will show how the multiple structures observed in this complex system can be used to characterize physical parameters of the protoplanet candidates. Conversely, we will also show how the suspected planets can shape the gas and dust distributions, truncate the inner disk, and launch a diversity of spiral wave patterns that could extend from the innermost regions out to large radial distances in the protoplanetary disk.

The inner disk of young stars: accretion, ejection, and planet formation

Detecting close-in planets around PMS stars - observational challenges, methods and results *(I)*

Jean-Francois Donati (1) (presenting author)

1 CNRS, Toulouse, France

In my talk i will recall the challenges observers have to face to detect and characterize close-in planets around PMS stars, using either precision photometry or velocimetry. I will then review results obtained so far with both techniques. (abstract to be extended after the deadline)

The inner disk of young stars: accretion, ejection, and planet formation

Dust evolution and planetesimal formation in the inner parts of the protoplanetary disk *(I)*

Joanna Drazkowska (1) (presenting author)

1 Max Planck Institute for Solar System Research, Göttingen, Germany

Planetesimals are the first gravitationally bound building blocks of planets, precursors of asteroids and comets in today's Solar System. Their formation is one of the major gaps in the state-of-the-art planet formation theory. Because of the barriers to dust growth, it is challenging to provide the conditions needed for forming these kilometer-sized objects. I will discuss the recent developments in dust evolution and planetesimal formation models. I will show that the first planetesimals are more likely to be formed in the inner regions of the protoplanetary disk, where the dust evolution timescales are short and the water snow line creates a privileged location by locally enhancing the density of pebbles.

Modelling Dust Growth in the Rings of Planet-Forming Discs *(P)*

Amena Faruqi (1) (presenting author), Farzana Meru (1), Richard Booth (2)

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Recent observations have shown dust rings to be a common feature of protoplanetary discs, located at various radial locations within the disc. Such features may be caused by embedded planets. However, previous studies to explain these features have typically excluded the growth of dust in these rings from theoretical models - simulating this growth could further our understanding of the mechanisms of planet formation and, in particular, how the planet formation process may proceed in the inner disc. In this poster, I will present my work investigating whether or not dust gathered in the rings of protoplanetary discs is susceptible to growth and how the presence of a planet can influence this process by altering the dust distribution in the inner disc. In order to achieve this, FARGO3D was used to run hydrodynamical grain growth simulations for a range of disc and planet properties. These models will be discussed and compared to consider how different factors may influence dust growth in rings and how viable this mechanism is for sequential planet formation.

Radial velocity monitoring of V1298 Tau with SPIRou to estimate the mass of the more massive planet of this system *(O)*

Benjamin Finociety (1) (presenting author), Jean-François Donati (1)

1 CNRS - IRAP, Toulouse, France

Improving our knowledge of star/planet formation and evolution requires guidance from both transit photometry and velocimetry to further charaterize young planetary systems and constrain mass-radius relations. Only 7 planets younger than 25 Myr have well-measured radii thanks to the detection of photometric transits. V1298 Tau (~23 Myr) hosts 4 of these 7 planets making this target quite unique. In this presentation, we will present results obtained from a thorough spectropolarimetric monitoring of this star with SPIRou, from end-2019 to early-2022 in the framework of the SPIRou Legacy Survey (SLS) and within the PI programme of Benjamin Finociety (run ID 21BF21). In particular, we are able to estimate the mass of the more massive planets of this system, consistent with previous studies, and to further constrain the orbital period of the planet e. We will also focus on two young weak-line T Tauri stars (< 2 Myr), namely V410 Tau and LkCa 4, for which no massive close-in planets have been detected yet, reporting upper limit on the mass of potential planets orbiting these stars, based on SPIRou monitoring of these stars in the framework of SLS.

The inner disk of young stars: accretion, ejection, and planet formation

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An accretion survey of Class I protostars *(O)*

Eleonora Fiorellino (1) (presenting author), ?ukasz Tychoniec (2)

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The low-mass stars accretion process is well investigated for Class II Young Stellar Objects (YSOs), but not for younger sources as Class 0 and I protostars. This is due to the fact that protostars are embedded in their envelope and it's hard to observe the photosphere of the forming star and the Balmer jump. Thanks to a self-consistent method based on empirical relation which links the accretion luminosity to NIR accretion tracers, we present the first survey of the mass accretion rate (Macc) in a sample of about 60 Class I in different star-forming regions within 500 pc. We also present for the first time the existence of a relation between Macc and the disk mass (Mdisk) of these sources. The main results we found are: 1) Macc is higher in Class I than in Class II, but not high enough to explain the stellar mass (Mstar) we observe in Main Sequence (MS) stars, suggesting that either most of the Mstar is accreted during erlier stages, or it is due to eruptive accretion; 2) most of the Class I in our sample lie in the Mdisk-Mstar instability region, suggesting that eruptive accretion could be more common than expected during the protostellar phase: 3) the slope of the Macc-Mdisk relation is flatter for Class I than for Class II and can't be described by current models based on viscous and/or MHD winds models.
In this talk I will describe our method, present these result and their impact on planet formation, and discuss possible future steps.

The inner disk of young stars: accretion, ejection, and planet formation

Dipper Stars: A Serendipitous Window on the Realm of Planet Formation

(P)

Eric Gaidos (1) (presenting author)

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Variability is one hallmark of T Tauri stars and this characteristic could be a key to unlock the secrets of inner planet-forming disks. The Kepler mission revealed thousands of diverse planetary systems, and one goal of exoplanet research is a predictive theory relating conditions in a protoplanetary disk to these varied outcomes. But spatial scale is an observational challenge: at the distance of the nearest star-forming regions, the inner disks corresponding to the orbits of most planets are unresolved by ALMA and too faint or over-resolved by infrared interferometry (GRAVITY). An alternative approach to studying inner disks is via time-series monitoring, exploiting their variability and using time as a proxy for separation via Kepler's third law. Dimming events, when dust from the disk or planetesimals occults the central star, inform about the structure and dynamics of the disk (and possible proto-planets) and can be a probe of the composition of the dust and any accompanying gas. This phenomenon was first described among Herbig Ae/Be stars (UXOrs) and extendeded to low-mass T Tauri stars "dippers" as CoRoT, Spitzer, and K2 observed nearby star-forming regions and young clusters. There are many possible underlying mechanisms causing dimming, including accretion streams, disk warps and instabilities, dusty winds, and evaporating planetesimals. and more than one could be operating around a given star. This technique is sensitive to relatively small amounts of dust, making it useful to investigate the later stages of disk evolution and planet formation when disks are clearing. Studies of the grain size, composition, and spatial distribution of the dust, as well as any accompanying gas, can help us trace the subsequent, hitherto hidden steps of planet formation. We present highlights from an ongoing multi-wavelength campaign to investigate dipper stars with ground- and space-based telescopes. The TESS mission has a central role because it has surveyed most of the sky, allowing for a greater diversity of stars to be investigated for dimming events, and at two or more epochs, allowing variation in behavior to be ascertained. Our campaign also includes a three-year Key Project on the Las Cumbres Observatory Global Telescope. Among recent findings: (1) There is evidence that variability can evolve on year-long time scales and that some dipper stars have a finite ``duty cycle"; This challenges some explanations for dipping and means that the fraction of stars which are dippers is higher than previously estimated. (2) Color-magnitude variability indicates extinction/reddening by sub-micron but super-ISM-size dust grains, suggesting intense fragmentation of larger dust, or size segregation in the upper layers of the disk more likely to occult the star. (3) We also used X-ray observations by the Swift satellite in parallel with TESS to measure a comparatively low dust-to-gas ratio of the occulting material around one dipper star. We conclude with a look towards the future, including triggered observations with larger telescopes by the ASAS-SN network and the Vera Rubin/LSST telescope, multi-epoch observations by JWST, and, longer term, the possibility of deeper and more contiguous observations by PLATO.

The inner disk of young stars: accretion, ejection, and planet formation

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New insights on planetesimal formation in turbulent disks *(P)*

Fabiola Antonietta Gerosa (1) (presenting author), Héloïse Méheut (1), Jérémie Bec (2,3)

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Protoplanetary disks turbulence is a complex and debated problem. The origin and amplitude of turbulence are still open questions, despite improving observational constraints. Yet the disks turbulent gas has a key role in affecting the dust dynamics and its growth toward larger bodies.
We therefore address this question through numerical simulations of turbulent Keplerain flows coupled to dust particles. We systematically explore two physical parameters in our 2D simulations: the flow angular velocity and the particle size. Using this original approach, we show that small particles can strongly cluster in eddies of the fast rotating flow, such as disks inner regions. Turbulence hence does not act as a diffusion process for dust, contrary to what commonly assumed. Thanks to innovative analysis tools we anticipate gravitational collapse and formation of planetesimals.
In this talk, I will present these promising results for planetesimal formation, as well as the more complex 3D approach.

Origins of the Inner Near-Resonant Kepler Planets *(O)*

Max Goldberg (1) (presenting author), Konstantin Batygin (1)

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Short-period super-Earths and mini-Neptunes encircle more than ~50% of Sun-like stars and are relatively amenable to direct observational characterization. Despite this, environments in which these planets accrete are difficult to probe directly. Pairs of planets that are close to orbital resonances provide a unique window into the inner regions of protoplanetary disks, as they preserve the conditions of their formation, as well as the early evolution of their orbital architectures. We present a novel approach toward quantifying transit timing variations within multi-planetary systems and examine the near-resonant dynamics of over 100 planet pairs detected by Kepler. Using an integrable model for first-order resonances, we find a clear transition from libration to circulation of the resonant angle at a period ratio of ~0.6% wide of exact resonance. The orbital properties of these systems indicate that they systematically lie far away from the resonant forced equilibrium. Cumulatively our modeling indicates that while orbital architectures shaped by strong disk damping, tidal dissipation, or planetesimal scattering are inconsistent with observations, a scenario with stochastic stirring by turbulent eddies in the protoplanetary disk reproduces several features of the data.

An ultraviolet view of an extended proto-stellar jet from BP Piscium

(P)

Keri Hoadley (1) (presenting author), Casey DeRoo (1), Hans Moritz Gunther (2), P. Christian Schneider (3)

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3 Hamburg Observatory, Hamburg, Germany

BP Piscum (Psc) is a bit of a stellar enigma - while it behaves like a rapidly rotating giant branch star, it harbors a gaseous, dusty disk and an extended jet with knotted and filament features akin to protostars with planet-forming disks. We present the discovery of FUV and NUV emission from BP Psc's extended jet, including its brightness and potential mechanism for creation in the knots and filaments of the jet. We compliment the UV emission analysis with recent optical coverage of BP Psc's jet from the DECaLS survey. We hope to show to that UV coverage of such extended, diffuse emission sources can be used as a powerful tool to reveal the physical conditions underlying interstellar shocks produced by such objects and ejection mechanisms that tie the properties of the jet to the inner workings of the protostar-to-disk connection.

Collisional evolution of dust and water ice in protoplanetary discs during and after an accretion outburst *(P)*

Adrien Houge (1,2) (presenting author), Sebastiaan Krijt (2)

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2 University of Exeter, Exeter, United Kingdom

Most protoplanetary discs are thought to undergo violent and frequent accretion outbursts, during which the mass accretion rate is multiplied by several order of magnitudes and remains elevated for decades. Such event temporarily increases the central luminosity and disc temperature, leading to the sublimation of ice species as snowlines move outwards. Ices being crucial in setting the collisional properties of dust aggregates, their sublimation leads to important modifications of the dust coagulation process, affecting also the formation of planetary building blocks (planetesimals). In this talk, I will present how an FUor-type accretion outburst alters the growth and appearance of dust aggregates at different locations in protoplanetary discs. We have studied the coupled coagulation of dust and ice before, during, and after an accretion outburst, using local Monte Carlo coagulation simulations. We will explore the importance of our findings in the context of planetesimal formation through the streaming instability (occurrence, properties, and structure). Then, we will briefly discuss the potential opportunities to use dust emission at mm-wavelengths as a tracer of past outbursts in discs, which would allow us to build a greater statistical estimates of such events (currently less than 50 events confirmed) to better constrain their cause and frequency.

A search of accreting protoplanets through SPHERE/ZIMPOL H alpha observations *(O)*

Nuria Huelamo (1) (presenting author)

1 CAB (CSIC-INTA), Madrid, Spain

Protoplanets embedded in disks are expected to accrete material from their surrounding media. As a result of this process, they can emit in accretion tracers like the H alpha line. In this poster, we show the result from SPHERE/ZIMPOL observations to detect accreting protoplanets around five stars with (pre-)transitional disks. They were obtained in the H alpha line and the adjacent continuum, combining spectral and angular differential imaging techniques to increase the contrast in the innermost regions close to the star. We do not detect any point-like source around any of the stars. When we compare our detection limits with different planetary models, we estimate an average upper limit to the accretion luminosity of < 10-4 Lsun at 200 mas, which is 2 orders of magnitude higher that that previously estimated from the extrapolation of the LHalpha - Lacc stellar relationship. We explain the lack of protoplanet detections as a combination of different factors, like e.g. episodic accretion, extinction from the circumstellar and circumplanetray disks, and/or a majority of low-mass, low-accreting planets.

Disc evolution on intermediate mass stars *(O)*

Daniela Iglesias (1) (presenting author), Olja Pani? (1), Mario van den Ancker (2), Monika Petr-Gotzens (2), Lionel Siess (3), Miguel Vioque (4), Ilaria Pascucci (5), René Oudmaijer (1), James Miley (4)

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Intermediate-mass stars (IMSs) represent the link between low-mass and high-mass stars, and cover a key mass range for giant planet formation. They are also known to lack of low-mass short period planets with semimajor axes < 0.6 au, therefore, we aim to further investigate the formation of this architecture around IMSs. In this talk, I will present the results of a spectroscopic survey of 241 young IMS candidates with IR-excess, the most complete unbiased sample to date within 300 pc. We combined VLT/X-Shooter spectra with photometric observations and Gaia DR3 distances to estimate fundamental stellar parameters such as Teff, mass, radius, age, and luminosity. We further selected those stars within the intermediate-mass range 1.5 ≤ M ▯ /M ▯ ≤ 3.5, and discarded old contaminants. We used 2MASS and WISE photometry to study the IR-excesses of the sample, finding 92 previously unidentified stars with IR-excess. We studied inner disc dispersal timescales for λ < 10 µm and found very different trends for IMSs and low-mass stars (LMSs). IMSs show excesses dropping fast during the first 6 Myr independently of the wavelength, while LMSs show consistently lower fractions of excess at the shortest wavelengths, and increasingly higher fractions for longer wavelengths with slower dispersal rates. In conclusion, this study demonstrates empirically that IMSs dissipate their inner discs very differently than LMSs, providing a possible explanation for the lack of short period planets around IMSs.

Astrophysical Jets : Simulations up to observable scales *(P)*

Thomas Jannaud (1) (presenting author), Claudio Zanni (2), Jonathan Ferreira (1)

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The most successful scenario to explain the origin of astrophysical jets requires the presence of a large-scale magnetic field anchored in a rotating object (young star or disk), extracting its rotational energy and transfering it to the jet to accelerate it. Besides generating an acceleration force, the interplay of the large-scale magnetic field and the associated electric currents provides a confinement mechanism similar to Z-pinch systems, used for example to confine hot plasmas in fusion devices. In order to provide a hoop stress able to compress the jet on such large scales, this Z-pinch requires a non-vanishing asymptotic electric current flowing inside the jet (Heyvaerts & Norman 1989). But linking this asymptotic current to the source remains a long standing unsolved problem.

As a first step towards this goal, we performed a set of 2.5D magnetohydrodynamic (MHD) simulations of non-relativistic jets emitted from keplerian accretion disks, using the PLUTO code. In these platform simulations, the disk is a boundary condition and only the jet acceleration and collimation are self-consistently computed. Thanks to our novel numerical method, our simulations have been successfully carried out at unprecedented time and spatial scales, reaching a steady state up to a distance larger than 5000 times the inner disk radius (Jannaud, Zanni & Ferreira 2023).

Magnetically driven jets emitted from disks of a large radial extent are found to systematically undergo an intrinsic recollimation towards the jet axis, as proposed in Ferreira (1997). This refocusing leads to the existence of several internal shocks, in particular when the jet interacts with an axial spine. This spine represents the outflow launched from the star (stellar wind) and the star-disk interaction zone (not self-consistently computed in our case). I will present the influence of such a spine on the recollimation properties of magnetic jets launched from accretion disks. Besides, it will be shown that such a recollimation pattern is maintained even for a jet-emitting disk of finite extent, as required by observations. Finally, I will discuss the influence of the external disk magnetic field and the position of the innermost disk radius (relative to the corotation radius) on jet collimation properties.

The inner disk of young stars: accretion, ejection, and planet formation

Mapping Accretion In Intermediate Mass Stars *(P)*

Ruhee Kahar (1) (presenting author), Aurora Sicilia-Aguilar (1), Justyn Campbell-White (1)

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Although substantial effort has been put into understanding the formation of low-mass stars and their planetary system, the knowledge of their intermediate mass counterparts is still lacking. For instance, accretion mechanisms on intermediate mass stars are unknown as their magnetic fields are too weak to sustain magnetospheric accretion.

I will present the primary stages in my study of time variability of accretion-related lines in young intermediate-mass stars, using the novel STAR-MELT code (Campbell-White et al., 2021), combined with long- and short-cadence spectroscopic and photometric data. The STAR-MELT code was developed to facilitate the analysis of time-resolved emission line spectroscopy of young stellar objects and can automatically extract, identify, and fit emission lines.

The 25 targets chosen for study comprise of spectral types B-K, which includes HAeBe stars as well as massive T Tauri stars that will eventually evolve into A or B type. These objects have well-known protoplanetary discs, and evidence of extinction by circumstellar material. The analysis data is newly received from CARMENES, as well as being supplemented by archival data, to assist us in distinguishing rotational modulation from accretion rate variations.

Emission and absorption lines with broad and narrow components, including metallic ones, are detected in these stars in a similar way to what is found in their lower-mass counterparts. The STAR-MELT code measures the variability in velocity and relative intensity for different lines and we aim to trace the structure of accretion columns and distinguish between different accretion mechanisms as they evolve over time. Our first results are that we observe rapid changes in the emission lines consistent with some degree of rotational modulation. The profiles are wind-dominated and could be related to non-axisymmetric winds.

We have also found, using TESS data, that in some cases we find periodic modulations, suggesting somewhat stable spots in intermediate mass-stars. The periods are shorter than in T Tauri stars, which is expected since we assume higher mass stars to be faster rotators. We determined whether the accretion is rotationally modulated, which would indicate that the accretion columns are discrete and non-axisymmetric.

By the end of this project, our plan is to have analysed the time-resolved spectroscopy so that the data can be used to explore the 3-D structure of accretion columns and unveil the planet-disc connection and the inner structure of protoplanetary discs.

Investigating the potential of spectral unmixing for protoplanet detection *(P)*

Elena Kokoulina (1) (presenting author), Valentin Christiaens (1), Olivier Absil (1)

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The origin of the observed diversity of exoplanet systems is still a matter of debate. High spectral resolution imaging can help us in our understanding of the physical, chemical, and orbital properties of imaged exoplanets. However, the existing methods which are applied to already identified planets essentially operate in the regime of supervised source-detection algorithm, e.g. cross-correlation technique, and can be very computationally expensive for discovering new planets. Also, cross-correlation relies on the already known model spectra for mature planets and is lacking spectral models for protoplanets, for which a data-driven approach would be of advantage. Moreover, with the advent of new instruments at the ELT like METIS, or with the upcoming hyperspectral data with JWST, a new unsupervised method which would not require a long computation time is needed.

Spectral unmixing is a well-known method outside of astronomy and is applied in a lot of fields. In astronomy this method is relatively rare, although it has recently been used on synthetic HARMONI data and then re-applied to SINFONI data to recover a signal from β Pictoris b. I first revisited this work by implementing and validating my own spectral unmixing code to a SINFONI dataset acquired on HD 142527 in order to retrieve a signal from the already known companion HD 142527 B. Then, in order to identify optimal parameters to use in the different steps of the algorithm (e.g. the number of sample spectra for the spectral unmixing and whether to use a prior spectral PCA step or not), I injected fake companions at different contrast levels and distances in a SINFONI dataset of PDS70. In this poster I will show the potential for detection of planets of different temperatures and extinction levels with different methods, including cross-correlation and different flavours of spectral unmixing (e.g., including PCA or not).

Shedding light in the inner disc of a massive young stellar object using nir- and mid-infrared interferometry *(P)*

Maria Koutoulaki (1) (presenting author), René Oudmaijer (1), Evgenia Koumpia (2), Abigail Frost (2), Willem-Jan de Wit (2)

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Massive stars impact a vast range of scales and processes, from re-ionisation of the Universe, to the physical and chemical evolution of galaxies, to regulation of the interstellar medium, to formation of star clusters, and even to formation of planets around stars in such clusters. The formation and/or migration of these planets are significantly affected by the structure of the young inner disc and the physical processes that rule its early evolution. In recent years, significant progress has been made in understanding the formation of high-mass young stellar objects (HMYSOs; i.e. M∗ ≥ 8 M?, Lbol ≥ 5x 103 L?). The latest observational and theoretical studies present evidence that HMYSOs are born in the same way as their low-mass counterparts, via disc accretion, rather than through coalescence of lower mass stars. While the existence of massive protostellar discs has now been established, little is known about how they eventually disperse, and how this is linked to the central protostar. A recent interferometric study at mid-infrared wavelengths (VLTI/MIDI) has shown substructures in the discs of 8 HMYSOs and one source showed a spiral-gap structure. These substructures could be the result of a forming companion, thus understanding their formation is of great importance since massive stars have a high binary fraction. Moreover, investigating their inner structure, where the mass transfer to the protostar takes place, gives us insights in determining the physical and dynamical characteristics, as well as the accretion/ejection processes in HMYSOs.

In this talk, I will present our results on M8 EIR which is a famous MYSO with a mass of 13.5 M?. From previous VLTI/MIDI interferometric observations an inner hole of around 30 au is needed to fit the SED and interferometric data simultaneously implying some dispersal mechanism is present within the inner environment of the source. The presence of a companion or photoevaporation are the most likely causes for the clearing. In this study we combine the VLTI instruments AMBER, GRAVITY, MIDI and MATISSE interferometric data in order to fit the continuum using radiative transfer modelling and understand if indeed there is an inner hole in the disc. Moreover, using the emission lines present in the GRAVITY data such as the Brγ, NaI and CO lines we investigate the accretion and ejection properties of the source and get a size of the gaseous disc. From the K-band continuum data we see evidence of emission close to the star and the emission lines come from a region closer to the star than the continuum emission.

The inner disk of young stars: accretion, ejection, and planet formation

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A VLTI view of the star/disc interface around Massive Young Stellar Objects. *(O)*

Evgenia Koumpia (1) (presenting author)

1 ESO, Santiago, Chile

With steady observational advances, the formation of massive stars is being understood in more detail. Numerical models are converging on a scenario where accretion discs play a key role. Also, binarity appears to be an inevitable outcome. Indeed, the vast majority of massive stars are found in binaries (up to 100%). Our understanding of the geometry and physical properties of the innermost regions of discs around massive stars and their associated binarity is sparse due to the rarity of such objects and the observational challenges, including the lack of adequate diagnostic lines in the near-IR.

In this talk, I will present the first systematic study towards a sample of Massive Young Stellar Objects (MYSOs) as observed with long-baseline near-infrared K-band interferometry on VLTI (GRAVITY, AMBER). Geometrical models are employed to derive the characteristic size of the 2µm continuum and ionised gas emission towards this sample of MYSOs and investigate binarity. MYSOs are placed in a luminosity-size diagram for the first time, and their location is directly compared to their low and intermediate-mass counterparts. In addition, the investigation on the origin of the ionised gas emission (Brgamma) points towards a disc-wind interaction. I will also present the first statistics on young high-mass binarity tracing 2-300 au separations and directly compare them to their pre-main and main sequence equivalents, reporting an increasing fraction with evolution.

Finally, we detect and spatially resolve the Na I doublet and He I transitions at au-scales towards an MYSO for the first time. The new observations in combination with our geometric models allowed us to probe the smallest -au- scales of accretion/ejection around an MYSO. We find that Na I originates in the disc at smaller radii than the dust disc and is more compact than any of the other spatially resolved diagnostics (Br?, He I, and CO). Our findings suggest that Na I can be a new powerful diagnostic line in tracing the warm star/disc accreting interface of forming (massive) stars, while the similarities between He I and Br? point towards an accretion/ejection origin of He I.

The inner disk of young stars: accretion, ejection, and planet formation

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Future instrumental perspectives for the observational study of young stars. *(I)*

Lucas Labadie (1) (presenting author)

1 University of Cologne, Cologne, Germany

Our understanding of the physical processes that regulate the evolution of the circumstellar environment of YSOs has made very significant progress in the last decade. For instance, the distribution of gas and dust in young inner disks has been mapped in detail, revealing large-scale trends as well as localized inhomogeneities, precisely interpreted in the context of theoretical models of disk evolution. The discovery of embedded protoplanets has shed new light on the disk-planet interactions, whereas gas diagnostics tracing inflow/outflow processes at the star-disk interface have a strong significance for describing the mechanisms of disk dispersal. These advances were made possible thanks to the steady improvement of observational capabilities across a large fraction of the electromagnetic spectrum, enabling multi-wavelength observational approaches and increased spatial resolution. It is therefore essential that the community of observers remains informed on the instrumentation serving their science. In this talk, I will attempt to review the development path of recent instrumentation capabilities - including space-based - that have enabled such a progress and describe some new perspectives. In the current and upcoming decades, the new suite of optical/infrared instruments at the VLT/VLTI (ERIS/GRAVITY+) and on the 39-m Extremely Large Telescope (METIS/MICADO/HARMONI) will offer unprecedented imaging and spectroscopic perspectives for the study of young stars and planet forming disks. Long-wavelength (millimeter) facility initiatives such as SKA and ngVLA may become relevant for this science in the post-ALMA era. Finally, the tight network of mid-size optical telescopes may be continued for dedicated scientific challenges related for instance to variability studies, a science case that will also benefit from upcoming survey telescopes.

The inner disk of young stars: accretion, ejection, and planet formation

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Inner disk view of variable accretion with optical interferometry *(P)*

Aaron Labdon (1) (presenting author)

1 European Southern Observatory, Santiago, Chile

Accretion is known to be highly variable across most young stellar objects, from subtle variability on long periods to rapid dramatic outbursts on short timescales in EXor and FUor objects. Such changes greatly influence and sculpt the characteristics, morphology and chemistry of inner disks, greatly impacting planet formation mechanisms. I present recent and new results from optical interferometric observations with the VLTI and CHARA arrays, with a particular focus on outbursting FU Orionis type objects, some resolved for the first time at such small scales. FUor outbursts, once thought to be limited to a subset of unusual stars, are now thought to be a ubiquitous process in star formation, making our understanding of these objects crucial. In this talk I will explore the phenomenon of boundary layer vs magnetospheric accretion, viscous vs passive disk heating and the presence of strong disk winds. This work highlights the power of high angular resolution observations, particularly optical interferometry, in diagnosing accretion and ejection processes from young stars.

The inner disk of young stars: accretion, ejection, and planet formation

Resistive heating in the inner regions of protoplanetary disks. *(P)*

Henrik Latter (1) (presenting author), William Bethune (2)

1 University of Cambridge, Cambridge, United Kingdom
2 ENS, Paris, France

The vertical temperature structure of a protoplanetary disc bears on several processes relevant to planet formation, such as gas and dust grain chemistry, ice lines, and convection. The temperature profile is controlled by irradiation from the central star and by any internal source of heat such as might arise from gas accretion. We conduct radiative non-ideal MHD simulations to better determine the importance of heating from resistive dissipation of magnetic fields in accreting laminar disc models. We hence obtain vertical temperature profiles for typical conditions in the inner disc (0.5-4 au). We find steady accreting equilibria that are driven by saturated Hall-shear unstable modes, as well as equilibria associated with global accretion-ejection structures. In both cases, we can achieve significant midplane heating for a sufficiently high opacity. In particular, strong magnetic fields can induce an order-unity temperature increase at the disc mid-plane, and even convection. These results demonstrate that magnetic fields can drive efficient accretion and heating in weakly ionized disks when MRI turbulence is absent.

Unraveling the chemical evolution of young planet-forming disks in their natal environment *(P)*

Romane LE GAL (1) (presenting author)

1 IPAG, Grenoble, France

There is mounting evidence that the composition and structure of planetary systems are intimately linked to their birth environments. During the past decade, several spectral surveys probed the chemistry of the earliest stages of star formation and of late planet?forming disks. However, very little is known about the chemistry of intermediate protostellar stages, i.e. Class I Young Stellar Objects (YSOs), where planet formation may have already begun.

In this talk, I will present the first results of a spectral survey we performed with the IRAM telescopes to investigate the chemistry of a sample of seven Class I YSOs located in the Taurus star?forming region. These sources were selected to embrace the wide diversity identified for low?mass protostellar envelope and disk systems. I will focus on the detections and upper limits of thirteen small (with maximum 3 atoms) C, N, O, and S carriers ? namely CO, HCO+, HCN, HNC, CN, N2H+, C2H, CS, SO, HCS+, C2S, SO2, OCS ? and some of their D, 13C, 15N, 18O, 17O, and 34S isotopologues. Together these species probe gas?phase C/N/O ratios, D? and 15N?fractionation, source temperature and UV exposure. I will present the substantial evidence we found of chemical differentiation among our source sample, some of which can be traced back to Class I physical parameters, such as the disk?to?envelope mass ratio (a proxy for Class I evolutionary stage), the source luminosity, and the UV?field strength. Overall, these results provide a first overview of the astrochemistry of Class I objects, however, I will show that interferometer observations are needed to go further and differentiate envelope versus disk chemistry.

The inner disk of young stars: accretion, ejection, and planet formation

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? Are magnetic fields shaping protoplanetary discs? *(I)*

Geoffroy Lesur (1) (presenting author)

1 CNRS, Grenoble, France

Over recent years, our understanding of protoplanetary disc (PPD) dynamics have changed dramatically. It is now believed that non-ideal MHD processes are playing a very important role in the formation and evolution of these objects. While direct measurement of magnetic fields in PPDs is still lacking, I will show in this talk that several observed features can easily be explained as a consequence of magnetised discs. In this context, I will revisit the origin of transition discs and planet-disc interaction in a magnetised disc.

The inner disk of young stars: accretion, ejection, and planet formation

Strengthening the case for vortex-induced inner planet formation *(P)*

Nathan Magnan (1) (presenting author), Henrik Latter (1)

1 University of Cambridge, Cambridge, United Kingdom

In the inner regions of a protoplanetary disk, typically near 1 AU from the central star, the magneto-rotational instability transitions from a region where it is active to a region where it is dead. At this interface, a pressure bump forms, triggering the Rossby wave instability, which creates large-scale vortices. Such vortices may play a key role in the formation of inner planets, because of their tendency to trap pebbles. Precisely, it is the streaming instability (SI) that is thought to play an important role in planet formation, by forming dust clumps which may collapse gravitationally and form planetesimals. Some studies of the SI’s robustness found that it can only develop in regions of high dust density and narrow distribution in dust sizes. Because vortices capture a lot of pebbles and only pebbles, they offer the perfect conditions for the SI to grow. This is what makes vortices such excellent candidate sites of inner planetesimal formation. Unfortunately, it is unknown whether the SI can feed on a vortex flow. Here we address this question by developing an analytical model for dusty protoplanetary vortices, perturbing it, and studying the evolution of the perturbations. We find that protoplanetary vortices are prone to an instability brought by the dust, and specifically by its back-reaction onto the gas. We interpret this instability as a resonant drag instability that involves the same physics as the SI. This instability strengthens the case for vortex-catalysed inner planet formation

Forming super-Mercuries: The role of stellar abundances *(O)*

Jingyi Mah (1) (presenting author), Bertram Bitsch (1)

1 Max Planck Institute for Astronomy, Heidelberg, Germany

Super-Mercuries, rocky exoplanets with bulk iron mass fraction of more than 60%, appear to be preferentially hosted by stars with higher iron mass fraction than the Earth. It is unclear whether these iron-rich planets can form in the disc, or if giant impacts are necessary. We investigate the formation of super-Mercuries in their natal protoplanetary discs by taking into account their host stars' stellar abundances using a disc evolution model which includes the growth, drift, evaporation and recondensation of pebbles to compute the pebble iron mass fraction. The recondensation of outward-drifting iron vapour near the iron evaporation front is the key mechanism that facilitates an increase in the pebble iron mass fraction. We also simulate the growth of planetary seeds around the iron evaporation front using a planet formation model which includes pebble accretion and planet migration, and compute the final composition of the planets. Our simulations are able to reproduce the observed iron compositions of the super-Mercuries provided that all the iron in the disc are locked in pure Fe grains and that the disc viscosity is low. The combined effects of slow orbital migration of planets and long retention time of iron vapour in low-viscosity discs makes it easier to form iron-rich planets. Furthermore, we find that decreasing the stellar Mg/Si ratio results in an increase in the iron mass fraction of the planet due to a decrease in the abundance of Mg2SiO4, which has a very similar condensation temperature as iron, in the disc. Our results thus imply that super-Mercuries are more likely to form around stars with low Mg/Si < 1, in agreement with observational data.

WANDA: Winds And Disk structures here and Afar *(P)*

Carlo F Manara (1) (presenting author)

1 ESO, Garching, Germany

In this poster I will present the ERC funded WANDA group and their activities.
The WANDA project aims at tackling the question of when and how did the multitude of observed exo-planets form by investigating the origin of the ring-like and asymmetric structures observed in protoplanetary disks, the cradle of planets, and pushing such studies to the distant and massive star-forming regions, the locations that best represent the natal environments of the known exo-planets.
The WANDA team will employ a novel multi-wavelength and multi-technique observational approach, based on a combination of high-resolution spectroscopy, spatially resolved integral field spectroscopy, and high spatial resolution imaging at near-infrared and millimeter wavelengths. Here I will show the initial results of this effort, with a particular emphasis on what we are finding using the ULLYSES and PENELLOPE data.

A photometric and spectroscopic detection of a possible 24 d period in the CI Tau system. *(O)*

Rajeev Manick (1) (presenting author), Jerome Bouvier (1), Alana Sousa (1), Jean-François Donati (2)

1 CNRS, Grenoble, France
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The formation and evolution of exoplanets is a fascinating topic in astronomy, but it's difficult to study because only a few have been found around young stars. One area of research is the study of Classical T Tauri stars (CTTSs), which have disks in which planets are thought to either form or migrate to close-in orbits (~ 0.1 au). One of the main goals has been, therefore, to investigate the physical processes that govern the interactions between stars, disks and planets on such small scales. CI Tau is one such CTTS for which there have been claims of a planet at a period of around 9 days. There is now enough evidence to suggest that this period is actually caused by rotational modulation rather than a purported planet. However, a longer stable period of around 24 days is seen in both Kepler (K2) and Las Cumbres Observatory Global Telescope (LCOGT) light curves, as well as in some of the ESPaDOnS and SPIRou radial velocities. In this talk, I will present the 24-day modulation seen in CI Tau radial velocity and photometry, and will speculate on possible scenarios that could give rise to this observed behaviour.

Locating solid carbon reservoirs in the planet-forming region of protoplanetary disks with MATISSE *(O)*

Alexis Matter (1) (presenting author), Eric Pantin (2), Bruno Lopez (1), Elena Kokoulina (3), Christophe Pinte (4)

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Carbon is one of the most abundant components in the Universe. While silicates have been the main focus of solid phase studies in protoplanetary discs (PPDs), little is known about the solid carbon content, especially in the planet-forming regions (~0.1-10 au). This is especially important in the context of our own Solar System, which presents a substantial carbon depletion gradient from the outer regions (> 40 au) to the inner regions (< 5 au).
Fortunately, several refractory carbonaceous species such as hydrogenated nano-diamond and amorphous carbon as well as polycyclic aromatic hydrocarbons generate infrared (IR) features that can be used to trace the solid carbon reservoirs. The mid-IR VLTI instrument VLTI/MATISSE is so far the only instrument that can spatially resolve the inner regions (~1-10 au) of PPDs and locate, down to the au-scale, the emission coming from carbon grains thanks to its access to the L-band domain.
We present here the first results of such a spectroscopic investigation of solid carbon species down to the au-scale in several protoplanetary systems. First constraints could be obtained on the location of the onset of the carbon grains emission, their relative abundances with respect to the bulk of the dusty disk, and the dehydrogenation/destruction mechanisms affecting this grain population.

The inner disk of young stars: accretion, ejection, and planet formation

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Feeling the Heat: Planet Formation in Cluster Environments *(O)*

Karina Mauco (1) (presenting author), Carlo Manara (1), Amelia Bayo (1), Carlos Carrasco-González (2), Roberto Galván-madrid (2), Enrique Macías (1), Anibal Sierra (3), Jesús Hernández (4), Nuria Calvet (5), Marco Tazzari (6), Feng Long (7), Leonardo Testi (8)

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Disk evolution can be neatly summarized by the ratio of the mass accreted onto the star over the system age to the present-day disk mass, i.e. ~M. The Macc is probed by optical spectroscopy while Mdisk is estimated via (sub)mm interferometry. Furthermore, understanding how planets formed requires discerning how dust grows in protoplanetary disks. Since larger dust grains preferentially emit at longer wavelengths, it is necessary to integrate ALMA (sub)mm observations with data at longer wavelengths. For this reason, multi-wavelength studies of protoplanetary disks are mandatory to get a complete picture of the planet formation process.
Since most stars form in cluster environments surrounded by massive OB stars, external photoevaporation of protoplanetary disks is believed to also play a key role in planet formation. Yet observational confirmation lags due to difficulties in detecting externally driven photoevaporative winds and disentangling their effects from other processes. The best way forward is to combine stellar mass accretion rates and forbidden line ratios with disk masses for large samples to robustly test theoretical predictions. One way to achieve this is to characterize the Macc/M<disk ratio in young clusters. Only external photoevaporation yields Macc/M<disk >> 1 by dramatically reducing Mdisk. This process greatly reduces the lifetime of the system and hence the timescale for planet formation.With this in mind, we are conducting a spectroscopic survey, coupled with ALMA data, of protoplanetary disks in the σ Orionis cluster. Initial analysis of 31 observed targets reveals clear evidence of external photoevaporation with M_{acc}/M_{disk} > 1 for many sources, several of which also showed strong [NII] forbidden emission lines characteristic of highly ionized material. The idea is to combine flux-calibrated data from XSHOOTER (to get mass accretion rates and forbidden line ratios) and high-resolution MIKE observations (to get the shape and the velocity of the line profiles) with disk mass estimates from ALMA. With this dataset, we will constrain the angular momentum transport in the outer regions and study disk wind tracers (optical forbidden lines) with the goal of distinguishing external photoevaporation from other disk evolution mechanisms (e.g., viscous accretion, internal photoevaporation, planet formation) by constraining M_{acc}/M_{disk} in the cluster.

Since the innermost parts of the disks (<30 au) are mostly optically thick at all ALMA wavelengths (Zhu+2019), observations at longer wavelengths are desired in order to robustly estimate the mass of dust in protoplanetary disks. VLA bands of 7 mm and 1 cm, for instance, probe a much deeper layer in the disk and the emission is optically thin even down to 5 au. To get an idea of how optical depth effects affect our dust mass estimates, we are conducting a VLA survey of 27 disks in the Taurus-Aurigae region. Our objective is to obtain high-quality data of their dust emission at 7 mm. By observing at an optically thinner wavelength, we will estimate more reliable dust masses for comparison with previous ALMA estimates to better constrain the reliability of dust masses at ALMA wavelengths.

High Resolution Spectroscopic Survey of a Large Population of Herbig Ae/Be Stars with HARPS/GIANO *(P)*

Robin Mentel (1) (presenting author), Rebeca Garcia-Lopez (1,2), Antonella Natta (2), Pauline McGinnis (2), Fabrizio Massi (3), Alessio Caratti o Garatti (2,4)

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In this talk I present the first high-spectral resolution (R=115,000 for the optical, and R=50,000 for the NIR) unbiased survey of 25 Herbig Ae/Be stars performed with the instruments HARPS and GIANO at TNG. This is the first survey observing simultaneously the full spectral range from 380 nm to 2,450 nm at such high spectral resolution, representing an unique opportunity to constrain the properties of the gas in the inner disk regions of Herbig Ae/Be protoplanetary disks, and to probe the physical processes driving this emission.

In this talk, I present our results on the Herbig Ae star HD141569 as an example of the potential of this survey. It is a A0 star with 2.1 solar masses at 110 pc distance (V=7.1) with virtually no IR-excess. This source shows bright emission in the Hydrogen Balmer, Paschen, and Brackett series as well as in the [O I] 6300A line. Our high spectral resolution data show that these lines are double peaked. In order to constrain the physical properties of the gas emitting region we have developed a LTE disk model. Our model predicts that the lines arise from hot and dense gas in the innermost disk, at most a few stellar radii away from the stellar surface.

Sandwiched Planet Formation: restricting the mass of the middle planet *(P)*

Farzana Meru (1) (presenting author), Matthew Pritchard (1), Sahl Rowther (1), David Armstrong (1), Kaleb Randall (1)

1 University of Warwick, Coventry, United Kingdom

We conduct gas and dust hydrodynamical simulations of protoplanetary discs with two embedded planets to determine the impact that a second planet located further out in the disk has on the potential for subsequent planet formation in the region locally exterior to the inner planet. We show how the presence of a second planet has a strong influence on the collection of solid material near the inner planet, particularly when the outer planet is massive enough to generate a maximum in the disk's pressure profile. This effect in general acts to reduce the amount of material that can collect in a pressure bump generated by the inner planet. When viewing the inner pressure bump as a location for potential subsequent planet formation of a third planet, we therefore expect that the mass of such a planet will be smaller than it would be in the case without the outer planet, resulting in a small planet being sandwiched between its neighbours - this is in contrast to the expected trend of increasing planet mass with radial distance from the host star. We show that several planetary systems have been observed that have a smaller planet sandwiched in between two more massive planets. We present the idea that such an architecture could be the result of the subsequent formation of a middle planet after its two neighbours formed at some earlier stage.

Jet and disk-wind structurs: the effect of heating on the central jet composition at small scales. *(P)*

Chadi Meskini (1) (presenting author), Christophe Sauty (1,2), Alexandre Marcowith (1), Valentin Brunn (1)

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2 Laboratoire Univers et Théories (LUTh), Paris, France

Context. Theoretical arguments as well as observations of young stellar objects (YSO) support the presence of a diversified circumstellar environment; a stellar jet is thought to account for most of the stellar spin down and a disk wind outflow for the observed high mass loss rate, thus playing a major role in the launching of powerful jets. RY Tau, for instance, is an extensively studied intermediate mass PMS. Observational data reveal jets at a small scale called microjets. Nevertheless, we are still unsure of the part microjets partake at a large scale.
Aims. The goal is to investigate the spatial stability and constitution of the central jet at a large scale by mixing the stellar and disk components.
Methods. After separately studying the numerical evolution of each component type, namely, the disk and stellar analytical wind solutions, we proceed to mix the two models inside the computational box. We additionally, replace the artificial polytropic equation linking pressure and density used to close the MHD system of equations by an analytical expression of heating which determines the heating exchange rate. We then introduce two parameters to control the spatial extent of the heating as well as its intensity.
Results. The central jet and the surrounding disk are strongly affected by these two parameters. We separate the results in three categories, which show different emissivity, temperature, and velocity maps.

Connecting the disk dispersal phase to magnetic morphology-driven stellar spin down *(P)*

Kristina Monsch (1) (presenting author), Cecilia Garraffo (1), Jeremy J. Drake (1), Giovanni Picogna (2), Barbara Ercolano (2)

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The high energy radiation emitted by young pre-main sequence stars can have a strong influence on their subsequent rotational evolution at later stages. This is because XEUV-driven photoevaporation is one of the major drivers of the dispersal of circumstellar disks, which surround all newly born stars during the first few million years of their evolution. Since the photoevaporative wind mass loss rate is mainly a function of stellar X-ray luminosity, the lifetimes of protoplanetary disks are primarily set by the X-ray emission of their central star. Stellar rotation and X-ray activity are therefore tightly coupled, as the circumstellar disk prevents the star from spinning up as it contracts through the disk-locking phase. Using a magnetic morphology-driven stellar spin-down model, we show that the duration of disk-locking has a significant impact on the subsequent rotational evolution of young stars. We further find that the bimodal rotation period distribution of a number of older open clusters, such as the Pleiades or Praesepe, can be successfully recovered, strengthening our conclusion that realistic disk dispersal mechanisms need to be considered when modelling the rotational evolution of solar-type stars.

Coexistence of refractory rich and refractory poor planetesimals in the inner solar system: implications on the structure of the disk *(I)*

Alessandro Morbidelli (1) (presenting author)

1 CNRS/Observatoire de la Côte d'Azur, Nice, France

The Al/Si and Mg/Si ratios in non-carbonaceous chondrites are lower than the solar (i.e., CI-chondritic) values, in sharp contrast to the Earth and, possibly to the Angrite parent body, which are enriched in refractory elements and have Mg/Si ratios larger than solar. Because the streaming instability allows the formation of planetesimals only where the dust/gas ratio is locally enriched, this suggests that the inner solar system planetesimals formed at two sites: (i) the silicate sublimation line, where the recondensation of Si enhances the dust/gas ratio and produces Si enriched objects (a.k.a. refractory depleted) and (ii) a closer-to-the-Sun pressure bump that captured the refractory component surviving from the sublimation of Si from the dust, also enhancing the local dust/gas ratio and producing refractory reach objects. Both the pressure bump and the Si-sublimation line should have been located near 1 au, to explain the concentration of mass in the terrestrial planet region, implying that the solar system protoplanetary disk was initially very hot (T~ 1 400 K @ 1 au). Moreover, in order to capture small refractory dust, the pressure bump should not have been produced by a mechanism that reduces the surface density of the gas near the Sun without enhancing its radial velocity component. We argue that magnetic winds may provide such a mechanism.

The inner disk of young stars: accretion, ejection, and planet formation

Formation of close-in planetary systems: comparison of theory and observation *(I)*

Christoph Mordasini (1) (presenting author)

1 University of Bern, Bern, Switzerland

This talks reviews theoretical aspects of the formation of planetary systems at small orbital distances. While absent in the Solar System, observations of extrasolar planets have revealed that close-in low-mass / small-radius planets are a very common outcome of the planet formation process. It is also the population for which we today have the largest number of observational constraints, both of statistical nature but also for some well-characterized individual systems. The talk will first present important theoretical concepts for the formation of close-in planets, like the early transport of small building blocks, the planets' growth via pebbles, planetsimals, and giant impacts, the accretion of gas, interactions with the nascent protoplanetary disk and longer-term effects related to the proximity to the host star. Various mass scales governing the outcome of the formation process that are relevant for different end-member scenarios will be discussed, for example for in situ growth via giant impacts versus assembly outside of the iceline followed by orbital migration. In the second part, theoretical predictions will be compared with observations regarding different statistical constraints (e.g., frequency of planet types, multiplicity, eccentricity and inclination, dependency on stellar properties like [Fe/H], system architecture, peas-in-a-pod pattern, or the frequency of mean motion resonances). Finally, the radius valley will be discussed and how it might be crucial to understand the formation of close-in planets.

Nonideal MHD Simulations to Understand the Temperature Structure of Protoplanetary Disks *(P)*

Shoji Mori (1) (presenting author), Xuening Bai (2), Kengo Tomida (1)

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Understanding the thermal structure of protoplanetary disks is crucial to know where and when rocky planets formed. This is because rocky planets would have formed inside the water-snow line. How the disk is heated depends on the disk dynamics. Classically, the disk dynamics are assumed to be controlled by some turbulence, which is expected to be generated by magneto-rotational instability. However, this instability is not active, especially around a few au, i.e., a rocky planet-forming region. Thus, we need to reconsider the heating mechanism of such inner disk regions in order to predict the snowline location correctly and to know the environment of rocky planet formation. In addition, understanding the thermal structure around a few au from the star should also produce insight into the origin of close-in planets orbiting a few 0.1 au.

In this talk, I will present the results of 2D global, radiative, non-ideal MHD simulations of protoplanetary disks. We consider full low-ionization ("nonideal MHD") effects because protoplanetary disks are basically weakly ionized. The radiative transfer is calculated by a simplified method: the heating/cooling in the optically thin region is treated as a source term, and those in the optically thick region as a diffusion term. Global MHD simulations allow us to consider proper energy conversion due to gas accretion and to consider Joule heating due to global magnetic structures (curvatures and kinks). The simulation shows that while there are strong current layers that cause the Joule heating, they do not significantly heat the disk midplane. As a result, the temperature structure of protoplanetary disks, even at a few au, is determined mainly by irradiation heating. In addition, we will report repeated episodic gas accretion at the disk surface.

Extreme Evaporation of very young gas giant planets -- implications for disc structure and evolution at ~ 0.1 Myr ages. *(O)*

Sergei Nayakshin (1) (presenting author), James Owen (2), Vardan Elbakyan (1)

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The brightness of the prototypical low mass protostar FU Ori suddenly increased to hundreds of Solar luminosities some 85 years ago and remains elevated to this day. While disc accretion onto the star is the undisputed origin of the outburst, several competing disc models exist. Recent interferometric observations (Lykou +22) reveal that the size of the actively accreting disc is only 0.3 AU. whereas photometric variability (Siwak +18) strongly suggest a hot spot in the disc orbiting the star at the distance of about 0.08 AU. Here we show that both of these facts are naturally explained if material that feeds FU Ori outburst originates in a giant (at least 5 Jupiter masses) planet orbiting the star at 0.08 AU. Furthermore, we report and study in detail a new physical process that escaped attention so far. We show that discs at this location have mid-plane temperatures up to $\sim$ 30, 000 K during well known Hydrogen ionisation (thermal instability, Bell & Lin 1994) bursts. Young gas giant planets embedded in such discs are susceptible to thermal opacity-limited extreme evaporation (EE). We build an analytical theory of the process, verify it numerically, and incorporate it into a time-dependent code of a disc with an embedded planet. We find that steady-state FUOR-like outbursts are ignited when moderately massive planets migrating in very young discs reach distances $\sim$ 0.1 AU from the star where thermal instability operates. Their Extreme Evaporation then injects the matter in the surrounding discs at rates exceeding 10^-5 Msun/yr, so that the planet becomes the main source of matter for the innermost disc. The planet is thus a miniature secondary star losing mass via thermally driven wind (not Roche lobe overflow as previous authors, including ourselves, believed). Our theory is consistent with disc viscosity constraints from simulations and observations, planet contraction tracks computed with the well known MESA code, and explains virtually every major observational fact known about FU Ori outburst. Our calculations are self-consistent and place significant constraints on the the structure of discs that can yield EE-fed bursts: these may only occur in discs with accretion rate excceding a few 10^-7 Msun/yr, and likely not older than 0.1 Myr. Similarly, only planets born by gravitational instability, and having accreted significant amounts of dust/pebbles from the disc, may be extended enough to participate in this process. We are therefore able to place interesting constraints on large scale disc viscosity of very young massive discs, and the speed with which these youngest systems evolve. Finally, we discuss what episodic outbursts tell us about similarities and differences in accretion of low and high mass stars. [Based on Nayakshin +23, submitted, and Elbakyan +21,23].

Star-disk interactions in the strong accretor T Tauri Star S CrA N *(P)*

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Among the solar-mass Classical T Tauri Stars (CTTS), some are strong accretors that exhibit strong emission lines along with a strong veiling of the photospheric lines of the star. These objects are still poorly understood (and studied). Yet they represent a unique opportunity to study and test the magnetospheric accretion phenomenon in a sustained regime (~100 times larger than in CTTS) along with every accretion-related phenomena from the inner disc (stellar/disc wind, jet launching, etc...). Recently, the advent of optical long-baseline interferometry with focal instruments sensitive enough has allowed to partially resolve the innermost regions of these objects with an angular resolution of a few stellar radii for the closest star-forming regions. In a complementary way, high resolution spectropolarimetry (in the visible and in the near-infrared) allows to derive the magnetic field topology and the size of the magnetosphere of the star.

In this communication, following the paradigm initiated with success on the CTTS DoAr44 (Bouvier et al. 2020a, b), I will present the unique results of a multi-technique observation of the strong accretor S CrA N. With infrared interferometric VLTI/GRAVITY observations, we partially resolved at a sub-astronomical unit scale the inner dusty disk in the K-band continuum (from 2 to 2.5µm) and the even more compact emitting region. One way to better understand which accretion-ejection phenomena dominates in the star-inner disk interactions is to compare this line characteristic size with the truncation radius, which we deduced from the topology of the magnetic field of the star. With high resolution spectropolarimetric observations of CFHT/ESPaDOnS in the optical domain (from 0.4 to 1µm) we derived such a topology and studied more directly the accretion/ejection processes through the kinematic analysis of several emission lines attributed to infalling/outflowing material. These combined observations help us to draw the structure of the inner regions of a strong accretor for the very first time.

To conclude, we will see that such studies will strongly benefit from CFHT/SPIRou observations for the kinematic analysis of infrared lines, and from the upgrade instrument VLTI/GRAVITY+ as the sensitivity improvement will allow the accretion flows to be temporally followed.

Infrared variability of young solar analogs in the Lagoon Nebula *(P)*

Camila Ordenes (1,2,3) (presenting author)

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T Tauri stars are low-mass pre-main sequence stars that are intrinsically variable. Due to the intense magnetic fields they possess, they develop dark spots on their surface that, because of rotation, introduce a periodic variation of brightness. In addition, the presence of surrounding disks could generate flux variations by variable extinction or accretion. Both can lead to a brightness decrease or increase, respectively. Here, we have compiled a catalog of light curves for 379 T Tauri stars in the Lagoon Nebula (M8) region, using VVVX survey data in the Ks-band. All these stars were already classified as pre-MS stars based on other indicators. The data presented here are spread over a period of about eight years, which gives us a unique follow-up time for these sources at this wavelength. The light curves were classified according to their degree of periodicity and asymmetry, to constrain the physical processes responsible for their variation. Periods were compared with the ones found in literature, on a much shorter baseline. This allowed us to prove that for 126 stars, the magnetically active regions remain stable for several years. Besides, our near-IR data were compared with the optical Kepler/K2 light curves, when available, giving us a better understanding of the mechanisms responsible for the brightness variations observed and how they manifest at different bands. We found that the periodicity in both bands is in fairly good agreement, but the asymmetry will depend on the amplitude of the bursts or dips events and the observation cadence.

The inner disk of young stars: accretion, ejection, and planet formation

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The angular-momentum transport between a star and its inner disk in 3D MHD simulations *(O)*

George Pantolmos (1) (presenting author), Claudio Zanni (2), Jerome Bouvier (1)

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Young stellar objects magnetically interact with the inner parts of their surrounding disks and accrete gas though two distinct regimes: the stable (via funnel flows) or the unstable (via tongues due to an interchange unstable disk). In this talk, I will discuss the outcome of three-dimensional MHD simulations of star-disk interaction showing that stable accretion is a key ingredient for a stellar spin-down, with a spin-down timescale of about one Myr, and thus, it can explain the observed slow rotation of classical T Tauri stars. The critical parameter, which characterises both the accretion state (stable/unstable) and the angular-momentum transport in the star-disk system, is the ratio between the disk truncation radius and the corotation radius (where the disk rotation rate matches the stellar rotation rate). Therefore, I will further demonstrate that the photometric variability arising from these two accretion regimes (with periodic or non-periodic/stochastic light curves) may indicate the rotational evolution state of the central object (spin-down vs. spin-up). Finally, I will show that non-axisymmetric numerical models suggest a new scaling between the disk truncation radius and the system global parameters (mass accretion rate, stellar mass and radius, magnetic field strength).

The inner disk of young stars: accretion, ejection, and planet formation

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The GRAVITY view of the innermost regions of protoplanetary disks

(O)

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Probing the inner rim of the protoplanetary disks where micron-sized dust grains grow to pebbles and larger bodies producing the first building blocks of planets, and investigating star-disk interactions at sub-astronomical unit scale are of utmost interest as they define the initial and environmental conditions for planet formation.
Since its installation in 2016, VLTI/GRAVITY has brilliantly illustrated the potential of the high angular and spectral resolutions to constrain these innermost regions of protoplanetary disks in the near-infrared K-band. With a sample of a hundred young stellar objects (YSO), from solar-like (namely the T Tauri) to high-mass YSO, the YSO GTO Large Program has gathered a large homogeneous data set allowing us to extend the Radius-Luminosity relation over more than 4 decades and to look for trends with the properties of the central star and the disk morphology (GRAVITY Coll. Perraut et al. 2019, 2021). We have investigated the origins of gaps in the innermost regions, measure (mis-)alignments between the inner and the outer disks over a sample of 20 transitional disks (Bohn, Benisty, Perraut et al. 2022), and tested proxies to investigate a potential evolutionary scenario between the different morphologies of the dusty disks. Thanks to its spectroscopic ability, GRAVITY has also led to the spatial resolution of the Hydrogen Br_gamma emitting regions around a sample of YSO, leading to the first resolution of the magnetospheric accretion regions around T Tauri stars (Bouvier, Perraut et al. 2020; GRAVITY Coll. Garcia-Lopez et al. 2020; GRAVITY Coll. Wojtczak et al. 2023).
In a near future, with its improved sensitivity and sky coverage, GRAVITY+ will drastically increase our sample: a more representative population of YSO, including the bulk of T Tauri stars in different star forming regions, will be reachable, as long as lower-mass young stars and younger embedded sources that would become observable with near-infrared interferometry for the first time. Combined within multi-technique and multi-wavelength campaigns, and with advanced radiative transfer and MHD simulations, the GRAVITY+ observations will be key to obtain a global picture of the inner parts of the protoplanetary disks.
In this talk, I will review the most striking results obtained with GRAVITY during its first 5 years of operation and illustrate the opportunities opened by GRAVITY+.

Modelling atomic and molecular disk wind tracers *(P)*

Christian Rab (1,2) (presenting author), Michael Weber (1), Tommaso Grassi (2), Barbara Ercolano (1), Giovanni Picogna (1), Paola Caselli (2), Wing-Fai Thi (2), Inga Kamp (3), Peter Woitke (4), Andrea Banzatti (5)

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Winds in protoplanetary disks play an essential role in their evolution and dispersal, particularly for the inner disk. However, what physical process is driving the winds is still unclear (i.e. magnetically vs thermally driven) and can only be understood by directly confronting theoretical models with observational data.

We use hydrodynamic X-ray photoevaporative disk wind models (e.g. Weber+ 2020) and post-process them with the thermo-chemical model ProDiMo (e.g. Woitke+ 2016) to calculate the temperature structure and chemical abundances. This allows us to produce synthetic observables for atomic and molecular disk wind tracers.

In the first study (Rab+ 2022), we directly compared our models to a sample of observations of the molecular hydrogen line at 2.12 microns and [OI] line at 0.63 microns (Gangi+ 2020). The photoevaporative disk wind model is consistent with the observed signatures of the blue-shifted narrow low-velocity component (NLVC), usually associated with slow disk winds, for six out of seven targets that show the NLVC in both lines. Furthermore, our results indicate that interpreting spectral line profiles by simple methods, such as the thin-disk approximation, to determine the line-emitting region can yield misleading conclusions.

We will also present new modelling that includes the CO ro-vib lines in the infrared. Those lines show time-variable absorption in the red-shifted part of the line profile but also narrow self-absorption features in the blue-shifted part (Banzatti+ 2022). With our models, we present an analysis of such data to study the origin of those features and to what extent they provide constraints on the wind velocities and densities.

Furthermore, we present the first results for modelling molecular disk wind tracers for a disk-wind model including an embedded planet to understand the planet's impact on the wind observables and if it is possible to identify clear planetary signatures in those observables.

Fully Global Non-Ideal MHD Simulations of the Inner Regions of Protoplanetary Disks *(O)*

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When describing the dynamics in the inner regions of protoplanetary disks, the dead zone interface (DZI) is crucial to explore because it (a) provides promising mechanisms for planet formation, such as pressure bumps and vortices, and it (b) influences the transport of large-scale magnetic flux, which itself controls the strength and nature of magnetically launched winds. These two phenomena are inherently linked and are strongly impacted by the complex non-ideal MHD effects present. However, they remain poorly understood due to a lack of direct observation and the complexity of the dynamics present. This work presents a detailed and methodical analysis of high cost, fully global non-ideal MHD simulations of the inner disk and its surrounding environment, which have been run using the new astrophysical code Idefix. Specifically, the work focuses on two key results. First, we explore the consequence of including non-ideal MHD effects and vertical structure on the 3D morphology, strength, and temporal evolution of the pressure bump, and its corresponding vortices, that form close to the DZI. Second, we outline preliminary work related to the transport of large-scale magnetic flux around the DZI, including an investigation into the structure, properties and time variability of MHD winds that are launched from the disk surface in the immediate environment of the DZI. This part of the work provides insight into the delicate relationship between radial accretion and outflow at the DZI, and its effect on planet formation mechanisms.

The inner disk of young stars: accretion, ejection, and planet formation

Synthetic Light Curves of Accretion Variability in T Tauri Stars *(P)*

Connor Robinson (1) (presenting author)

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Photometric observations of accreting, low-mass, pre-main-sequence stars (i.e., Classical T Tauri stars; CTTS) have revealed different categories of variability. Several of these classifications have been linked to changes in the mass accretion rate. To test how accretion variability conditions lead to different light-curve morphologies, we used 1D hydrodynamic simulations of accretion along a magnetic field line coupled with radiative transfer models and a simple treatment of rotation to generate synthetic light curves. We adopted previously developed metrics in order to classify observations to facilitate comparisons between observations and our models. We found that stellar mass, magnetic field geometry, corotation radius, inclination, and turbulence all play roles in producing the observed light curves and that no single parameter is entirely dominant in controlling the observed variability. While the periodic behavior of the light curve is most strongly affected by the inclination, it is also a function of the magnetic field geometry and inner disk turbulence. Objects with either pure dipole fields, strong aligned octupole components, or high turbulence in the inner disk all tend to display accretion bursts. Objects with anti-aligned octupole components or aligned, weaker octupole components tend to show light curves with slightly fewer bursts. We did not find clear monotonic trends between the stellar mass and empirical classification. This work establishes the groundwork for more detailed characterization of well-studied targets as more light curves of CTTS become available through missions such as the Transiting Exoplanet Survey Satellite (TESS).

Absence of apparent motion of spiral pattern in disk of CQ Tau *(P)*

Boris Safonov (1) (presenting author), Ivan Strakhov (1), Maria Goliguzova (1), Olga Voziakova (1)

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The study of spiral structures in protoplanetary disks is of great importance for understanding the processes in the disks, including planet formation. Bright spiral arms were detected in the disk of young star CQ Tau by Uyama et al. in the H and L bands. The spiral arms are located inside the gap in millimeter-sized dust, discovered earlier using Atacama Large Millimeter/submillimeter Array observations. To explain the gap, Ubeira Gabellini et al. proposed the existence of a planet with the semimajor axis of 20 au. We obtained multi-epoch observations of a spiral feature in the circumstellar envelope of CQ Tau in the Ic band using a novel technique of differential speckle polarimetry. The observations covering a period from 2015 to 2021 allow us to estimate the pattern speed of the spiral: -0.°2 ± 1.°1 yr-1 (68% credible interval; positive value indicates counterclockwise rotation), assuming a face-on orientation of the disk. This speed is significantly smaller than expected for a companion-induced spiral, if the perturbing body has a semimajor axis of 20 au. We emphasize that the morphology of the spiral structure is likely to be strongly affected by shadows of a misaligned inner disk detected by Eisner et al. We investigate possible application of differential speckle polarimetry in combination with adaptive optics.

Dynamical collapse of a pebble and gas cloud : constraints on the resulting planetesimals *(P)*

Paul SEGRETAIN (1) (presenting author), Héloïse MÉHEUT (1), Manuel MOREIRA (2)

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We address the gravitational collapse of dust clumps, formed in protoplanetary disks by mechanisms such as the streaming instability (e.g. Carrera and Simon, 2022) or dust trapping in vortical structures (e.g. Gerosa et al. 2023), and coupled to the surrounding gas. Our goal is to study the crucial impact of the resulting dynamics on the properties of the planetesimals.
In our poster, we thus consider the dynamical evolution of the collapsing dust clump, coupled with the surrounding gas, at a size scale small compared to that of the discs. While Shariff and Cuzzi (2015) consider the 1D spherical collapse of a pressureless fluid in an isothermal gas, we propose in this work a lagrangian approach with super-particles for the dust. Our approach allows for a 3D evolution with particles velocity dispersion, and different equations of state for the gas evolution. Exploring this parameter space, we not only study the time evolution of the dust density profile during the collapse, but also the characteristics of the gas: density, pressure, temperature. These results can open new understanding in the properties of planetesimals, including their temperature and chemistry, in protoplanetary disks and in the solar system.

The formation of misaligned planets in and around binary star systems *(P)*

Jeremy Smallwood (1) (presenting author)

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The majority of stars born in dense stellar clusters are part of binary star systems. Circumbinary discs of gas and dust commonly surround binary star systems and are responsible for accreting material onto the binary. The gas flow dynamics from the circumbinary disc onto the binary components have significant implications for planet formation scenarios in binary systems. Misalignments between the circumbinary disc and the binary orbital plane are commonly observed. A misaligned circumbinary disc undergoes nodal precession. For a low initial inclination, the precession is around the binary angular momentum vector, while for a sufficiently high initial inclination, the precession is around the eccentricity vector. Dissipation causes the disc to evolve to align coplanar to the binary orbital plane or perpendicular (i.e., polar) to the binary orbital plane. I present 3-dimensional hydrodynamical simulations and linear theory on the evolution of highly misaligned circumbinary discs. I show that polar-aligned circumbinary discs are favorable environments for forming polar circumbinary (P-type) planets. Moreover, misaligned and polar circumbinary material flows around each binary component, forming misaligned and polar circumstellar discs. These circumstellar discs undergo long-lived Kozai-Lidov oscillations that may prompt the formation of inner giant circumstellar (S-type) planets in binary star systems. The evolution of protoplanetary discs in and around binary star systems bears important implications for inner planet formation.

The inner disk of young stars: accretion, ejection, and planet formation

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Probing the inner disk and magnetospheric accretion region of CI Tau with VLTI/GRAVITY *(O)*

Anthony Soulain (1) (presenting author)

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For a few million years after the gravitational collapse that led to their formation, young stellar systems (YSO) remain surrounded by a circumstellar disk from which planets form. Otegi et al. (2022) revealed that most planetary systems consist of super-Earths or mini-Neptunes orbiting close to their host star. It is crucial to explore the physics of the star-planet-inner disk interaction in young stars, not only for the role it plays in the early evolution of solar-type stars (e.g., accretion/ejection, angular momentum) but also to define the environmental conditions that prevail at the time of planetary formation. CI Tau is so far the only pre-main sequence star still accreting from its surrounding disk claimed to host a hot Jupiter planet. The most exciting aspect of CI Tau regards its extreme magnetic field (3.7 kG) that disrupts the inner gaseous disk and generates accretion funnel flows down to the stellar surface. We propose to present our investigation of the inner region of CI Tau, aiming at reconnecting the different spatial scales of the system down to a few stellar radii (≤0.1 AU). We investigated this puzzling system using the long-baseline interferometry technique at three different epochs (2021, 3 nights in 2022). Thanks to the high spectral resolution of VLTI/GRAVITY (R=4000), we are both sensitive to the emitting dusty part of the inner rim (K-band continuum), and the magnetosphere itself traced by the Brγ emission line (2.1661 μm). In the continuum, we characterize the disk's inner rim, which appeared disconnected from the outer disk with a significant misalignment in inclination and position angle (Soulain et al. 2023). We report an internal cavity at 0.20 ± 0.02 AU that could infer the presence of a planet carving the inner part of the disk, reinforced by a recent hydrodynamical simulation (Muley et al. 2021). Additionally, the strong asymmetry (inferred from the non-zero closure phase) seems to move between our epochs and could be caused by a moving material within the disk (vortices? planets?). In the Brγ line, we detect a compact emitting region of 0.05 ± 0.01 AU strongly supported by our accreting magnetosphere models (Tessore et al. 2023). Interestingly, the two-day baseline allowed us to trace this accretion phenomenon during the same orbit. We used the differential phases (sensitive to the photocentre of the system) to follow the funnel flows them-self. An asymmetric solid rotation of the magnetosphere should induce a variable photocentre displacement, and we propose to present these critical new results

Near-infrared emission in accreting stars using the CFHT/SPIRou data

(O)

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Classical T Tauri stars (CTTSs) are known to be photometrically and spectroscopically variable on different time scales, from seconds to decades, due to various physical phenomena. In this study, we aimed to understand the dynamics of the magnetic star-disk interaction process in young stellar objects, specifically related to accretion and emission excess. We used a sample of accreting stars observed with the CFHT/SPIRou spectrograph to measure the near-infrared veiling across the YJHK bands and the parameters of the circumstellar emission lines to understand their origin and variability. We compared the computed veiling with accretion and inner disk diagnostics from photometric observations obtained from previous studies. Our data provide further evidence that the veiling in the infrared increases with wavelength, with veiling growing from the Y to the K band for most of the targets in our sample, similar to results found in previous literature. The infrared veiling agrees with the near-infrared emission excess obtained using photometric data. However, we also found a linear correlation between the veiling and the accretion properties of the system, indicating that accretion contributes to inner disk heating and, consequently, to the inner disk emission excess. Additionally, we showed a connection between the near-infrared veiling and the system's inclination with respect to our line of sight, which reflects the reduction of the visible part of the edge of the inner disk, where the near-infrared emission excess arises as the inclination of the system increases. We also plan to show some preliminary results concerning the variability of near-infrared circumstellar emission lines on the short and long time scales.

Anisotropic Ionizing Illumination from an M-type Pre-main Sequence Star *(P)*

Yuka Terada (1,2) (presenting author), Hauyu Liu (1,3), David Mkrtichian (4), Jinshi Sai (1), Mihoko Konishi (5), Ing-Guey Jiang (6), Takayuki Muto (7), Jun Hashimoto (8,10,12), Motohide Tamura (9,11)

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Pre-main sequence (PMS) stars typically have short rotation periods of a few days. They are known to power strong magnetic fields with the geodynamo effect, which subsequently dictates stellar accretion and launch of the magnetocentrifugal winds/jets. In addition, the luminous X-ray and UV feedback from these magnetic structures (e.g., loops) may dramatically affect the protoplanetary disk mass-dispersal and the formation/evolution of prebiotic molecules, which are crucial aspects for the understanding of the origin of life. Similar to the monitoring of sunspots over solar cycles, the diagnostics of the activities of the colossal cold spots on the PMS stars will provide invaluable information about these magnetic activities on the PMS stars. Thanks to the Kepler K2 and TESS mission, it has only recently become possible to perform long-duration (e.g., a few tens of days) monitoring observations to characterize the activities associated with cold spots without interruption.
In this work, we studied the activity on the stellar surface of DM Tau, one of the PMS stars, using the light curves obtained with the Kepler K2 and optical and near-infrared photometric monitoring observations. Periodic analysis of the K2 data shows that DM Tau spins for a period of 7.3 days. In addition, we found that nearly 50% of the surface of the host protostar is occupied by cold spots that are several hundred Kelvin cooler than the warmer side. We report on the results of the analysis of these optical observations, along with data obtained by the JVLA. The latter, which is tracing the ionized gas in the protoplanetary disk, seems to show variability on a timescale that is similar to what we found from the optical data.

Hydrogen lines formation in the close environment of young stars: Spectro-interferometric modelling of the Brackett γ line.

(O)

Benjamin Tessore (1) (presenting author), Anthony Soulain (1), George Pantolmos (1), Jérôme Bouvier (1), Christophe Pinte (1)

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Radiation plays a key role in many aspects of the evolution of young stars. The modelling of the spectral signatures coming from the environment of young stars is critical to understand the physical conditions in which they originate from.

Classical T Tauri stars are young (of a few million years old) cool and active stars presenting a strong photometric and spectroscopic variability. The interaction between the star's magnetic field and its accretion disc (star-disc interaction) is responsible for accretion and ejection processes leading to an excess of UV radiation and the formation of emission lines.

Most of the variability these stars show is attributed to the star-disc interaction.

The modelling of the spectral signatures coming from the environment of T Tauri stars is therefore needed to unveil the complex dynamics of this interaction, entangled in observations.

While numerical simulations of the star-disc interaction are able to reproduce various phenomena (winds and magnetospheric accretion) the predictions of synthetic observations from state-of-the art radiative transfer models are lacking. The coupling between numerical simulations and radiative transfer calculations however offers a promising way to disentangle observations.

In this talk, we aim to assess the complementarity between spectroscopic and interferometric observations in the characterisation of the inner star-disc interaction region of young stars, from both analytical and numerical models.

We use the code MCFOST to solve the non-LTE problem of line formation in non-axisymmetric accreting magnetospheres. We compute the Brγ line profile originating from accretion columns for different models. This spectral line is a prime diagnostic of magnetospheric accretion in young stars and is accessible with the long baseline near-infrared interferometer GRAVITY installed at the ESO Very Large Telescope Interferometer.

The inner disk of young stars: accretion, ejection, and planet formation

Dynamics of young star-inner disk interaction and impact of embedded planets: an observational perspective *(I)*

Laura Venuti (1) (presenting author)

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Technological advances over the last decades have allowed us to achieve an unprecedented view of protoplanetary disks around young stars. In particular, dedicated surveys of star-forming regions with Kepler/K2 have documented a large variety of time domain behaviors that can be found among young star-disk systems. These behaviors, ranging from ordered modulated patterns to stochastic and bursting patterns, reflect varying physical conditions within the inner disk and a gradient in mass accretion dynamics onto the star. For a select class of young stellar variables, known as dippers, favorable viewing geometries grazing the disk plane provide a direct window onto the structure of the inner disk regions and of the accretion streams that form there. At the same time, the isotropic outer disk inclinations that have been measured for dipper stars in ALMA surveys suggest that inner/outer disk misalignments may develop frequently during the protoplanetary disk phase, possibly tracing perturbations by a stellar companion or a planetary-mass object. During the talk, we will review these recent results and explore what these observations teach us regarding the dynamical evolution of young stars and their disks.

The inner disk of young stars: accretion, ejection, and planet formation

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Intermediate-mass forming stars are key for planet formation studies. New population, upcoming WEAVE data, and Galactic properties. *(P)*

Miguel Vioque (1) (presenting author), Ignacio Mendigutia (2), Rene Oudmaijer (3)

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Intermediate-mass young stellar objects (1.5-3.5 solar masses) have protoplanetary disks that are more massive, and have a higher fraction of detected structures than the disks around their lower mass T Tauri counterparts. For these reasons, it has been proposed that intermediate-mass young stellar objects host a larger fraction of forming planets. This, together with their youth and large disk-sizes, make them ideal candidates to study ongoing planet formation. However, the study of intermediate-mass forming stars has been historically hampered by the lack of a well-defined, homogeneous sample, and because few and mostly serendipitously discovered sources were known. As a consequence, many studies involving intermediate-mass star formation suffer from biases and lack of completeness, and we know much less about these sources than about the lower mass T Tauri stars.

Applying machine learning techniques to Gaia data, we have constructed a large and homogeneous catalogue of 2226 new intermediate- to high-mass forming stars, increasing by an order of magnitude the number of known objects of the class. This unique list of new intermediate-mass forming stars is an excellent dataset to conduct research on several open problems in star and planet formation. In the near future, this catalogue of new intermediate-mass forming stars will be observed by the WEAVE multi-object survey spectrograph. This will greatly enhance and complement the Gaia data products, allowing us to study and characterize the accretion and ejection phases of the Galactic population of intermediate-mass young stellar objects. To exemplify the upcoming WEAVE science, I present the results of a spectroscopic survey that targeted 145 stars from this catalogue. These observations allowed us to derive accretion rates and to study which accretion mechanism is predominant in different stellar mass ranges. I provide further evidence to the transition from magnetospheric accretion to boundary layer accretion happening at around 4 solar masses.

One long-standing question in star formation is how the clustering properties of forming stars depend on the stellar mass. To further exemplify the importance of these new sources, I also present a Gaia-based analysis on the clustering properties of low, intermediate, and high-mass forming stars, using the largest sample ever considered. I conclude this presentation with a description of the planned research on a newly identified population of disks around these new intermediate-mass young stellar objects.

Primordial dust rings and the first generation of planetesimals in gravitoviscous protoplanetary disk *(O)*

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Dead zones in the innermost disk regions play an important role in the planet formation models, acting as dust traps and facilitating planetesimal formation. An important prerequisite for the dead zone formation is a radially varying mass transport rate through the disk. This can naturally be achieved in the layered disk model, in which the MRI-induced turbulence is suppressed in the innermost disk regions owing to insufficient ionization. The corresponding viscous alpha-parameter has a deep minimum at the position of the dead zone and peak values elsewhere in the disk.

However, recent observations and numerical simulations indicate that the MRI turbulence can be suppressed throughout most of the disk extent. This reduces the viscous mass transport in the entire disk and makes local dust concentrations problematic. Disk magnetocentrifugal winds may mitigate the problem but their efficiency crucially depends on the magnetic field geometry.

In this talk, we will demonstrate that taking disk self-gravity into account completely changes the long-term evolution of protoplanetary disks with suppressed MRI. Gravitational instability (GI) naturally has a spatially varying efficiency of mass transport through the disk, being most efficient in the outer and intermediate disk regions and diminishing in the innermost disk where temperature and sheer are too high to sustain GI. The associated gravitoturbulence and the alpha-GI parameter have a deep minimum in the innermost disk, resulting in the formation of a GI-driven dead zone around 1 au. This region is prone to efficient dust growth, development of the streaming instability, and formation of a first generation of planetesimals as early as 10~kyr after disk formation.

The inner disk of young stars: accretion, ejection, and planet formation

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The interplay between accreting planets and photoevaporative disk winds *(O)*

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Disk winds and planet-disk interactions are two essential mechanisms that drive the evolution of protoplanetary disks. While winds are capable of removing material from the disk, eventually dispersing it from the inside-out, massive planets can shape the disk by creating sub-structures such as gaps and spiral arms.

We perform three-dimensional hydrodynamic simulations of photoevaporating disks that host a jupiter-like planet with the aim to study the interplay between disk winds and the sub-structures that are created by the planet. By tracing gas-flows in the disk and wind, we are able to study how photoevaporation, in combination with a planetary gap, redistributes material along different disk radii.

We will present new results that show how the wind can transport gas from the inner disk (~2 au) into the planetary gap as well as across the gap to the outer disk and that photoevaporation can significantly increase the accretion rate onto the planet. We will also show that this opens up new accretion pathways that lead through the wind, allowing material from the inner disk to be accreted that cannot reach the planet in models without a wind. Tracking the environment along the different pathways will eventually allow us to study the effect on the chemistry and composition of accreting matter and to explore how photoevaporative winds may be able to explain the abundances of refractory inclusions in meteoritic records from our own solar system.

The inner disk of young stars: accretion, ejection, and planet formation

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Towards Planetary Population Syntheses in MHD Wind Driven Discs

(P)

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The ever rising number of discovered exoplanets sets important statistical constraints on planetary system properties on a population level. These constraints are fundamental for planet formation theory. By constructing so called global planet formation models, we are able to evolve a large number of systems, providing us with synthetic populations of planetary systems that can be compared with observations - putting thereby planet formation theory to the quantitative statistical test.

The evolution of the protoplanetary disc is one of the most fundamental parts of such a model as it controls the material from which the planets accrete and determines how planets migrate. To date, the approach of planetary population syntheses has been exclusively carried out using the classic approach of smooth, viscous discs with a constant alpha-viscosity. However, the recent shift towards MHD wind driven disc evolution rises the question of how this will shape the synthetic populations.

We have developed a new 1D vertically integrated global disc model that also includes the effects of magnetically driven disc winds and viscosity transitions in the inner disc. With emphasis on planet migration and growth, we study how different physical processes induced by this new disc model influence planet formation on a population level. Here, the inner disc of <1AU plays a crucial role as its evolution determines the final location of close-in planets. At the same time, this region is well characterised in terms of observed planets, making the comparison between theory and observation interesting.

In the end, this will enable us to bring the planet formation theory forward, keeping up with the important latest developments in the disc field.

Spatially resolved Brackett gamma emission in the star-disk interaction region of T Tauri stars *(P)*

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Atomic hydrogen Brackett gamma line emission from within the innermost parts of the accretion disk of young stellar objects (YSOs) is tied to gas temperatures in excess of 6000 K. While disk temperature profiles in more intermediate mass Herbig type YSOs allow for these conditions to be fulfilled, the disk environments in T Tauri stars are generally thought to be too cool to produce significant amounts of Brackett gamma radiation. For these low mass sources, hot hydrogen line emission is much more specifically associated with magnetically driven heating mechanisms and thus serves as a potential tracer of the interaction between the strong magnetic fields reported for those kinds of objects and the inner disk.
Most prominently among those mechanisms stands the idea of magnetospheric accretion, according to which the inner disk is magnetically truncated on the order of a few stellar radii. Instead of accreting in the disk plane, the gas is then funneled in magnetically heated columns onto the stellar surface at high latitudes, creating a highly compact region close to the star from which Brackett gamma radiation can originate.
Other mechanisms potentially producing Brackett gamma emission include magnetically driven outflows, coming in the form of winds in which the material gets swiftly heated to temperatures comparable to those found in the accretion columns. Such winds are either launched from the disk surface itself, the stellar polar region or the disk-magnetosphere interface, making them capable of contributing to the Brackett gamma emission profile at different, and potentially much more extended, spatial scales, reaching possibly even beyond the dust sublimation radius.
To better understand these competing influences, we observed a sample of seven T Tauri objects (RU Lup, AS 353, TW Hya, DoAr 44, DG Tau, S CrA N, VV CrA) with GRAVITY, the K band beam combiner of the Very Large Telescope Interferometer (VLTI).
We made use of the high spatial resolution provided by very long baseline interferometry to spatially resolve and constrain the Brackett gamma emission regions in our targets. We also compared the interferometric signatures, obtained across multiple channels in the Brackett gamma line, against synthetic observables derived from a radiative transfer model of the magnetospheric accretion region.
We found that only the weakest accretors in our sample were well described by the pure magnetospheric accretion case. For most of the intermediate to strong accretors, we found evidence for more extended Brackett gamma regions, suggesting the presence of multiple emission components that lead to more complex interferometric signatures.

The conditions for warping and breaking protoplanetary discs *(O)*

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The study of warped discs was once limited to the viscous accretion discs around black holes. Now, ALMA and SPHERE have revealed that the warping and breaking of protoplanetary discs is not uncommon and there is growing interest in the planet formation community in these effects. Warping and breaking change the disc structure in the inner few au and alter the evolution of the disc, for example by enhancing the accretion rate and changing the chemical composition. However, our understanding of the conditions under which protoplanetary discs warp and/or tear remains far more limited than for thin, viscous black hole discs. We have produced and analysed a suite of high resolution simulations of wavelike circumbinary discs to elucidate the parameters that affect the dynamical evolution of misaligned protoplanetary discs. I will present the conclusions from our modelling and discuss what affects whether and where a protoplanetary disc will break, how this differs to the commonly referenced theoretical predictions and what it means for interpreting observation of warped and broken protoplanetary discs.

The inner disk of young stars: accretion, ejection, and planet formation

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The role of MHD turbulence in the launching of jets and winds from magnetized accretion disks *(P)*

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The properties of collimated optical jets in young stellar objects (YSOs) are closely linked to the mass flux emitted from accretion disks. Most observations of these jets are fairly well reproduced by so-called « disk winds », which are actually magnetically driven, super-Alfvenic outflows from keplerian accretion disks (Ferreira 1997, Jacquemin-Ide et al. 2019). However, they require a rather large mass flux and correspondingly a small magnetic lever arm parameter (e.g. Tabone et al 2017, Lee et al 2021 and references therein). This has been achieved by including some additional heating at the disk surface, argued to result from irradiation from the star and the accretion shock (Casse & Ferreira 2000b).

On the other hand, these YSO optical jets are launched from the innermost disk regions, which are expected to be ionized enough to undergo a self-sustained magnetohydrodynamic (MHD) turbulence (see e.g. Combet et al 2010). The influence of such a turbulence in Jet-Emitting Disks (JEDs) has been modeled so far only through the use of anomalous viscosity and magnetic diffusivity. But state-of-the-art 3D global MHD numerical simulations highlighted the importance of a magnetic turbulent pressure within accretion disks (Jacquemin-Ide et al. 2021). Such a turbulent pressure has never been included in any accretion-ejection model.

In this work, we incorporate this turbulent magnetic pressure and perform a complete exploration of the parameter space for isothermal jets. We elucidate its effect on the jet properties and in particular on the link between the magnetic lever arm and the disk ejection efficiency.