The Star Formation Newsletter

A community newsletter on Star and Planet Formation research

No. 363 — 27 March 2023

Editor: João Alves www.starformation.news

Links to sections

Interviews	Reviews	Perspective	Favorite objects	Archive
Meetings	Jobs	New PhDs	Announcements	Books

Cover image caption

Detail of the "Mystic mountain" in the Carina Nebula, carved by the radiation and stellar winds from the Trumpler 14 cluster (located towards the top of the image). At about 2.6 kpc from Earth, and for times larger than the Orion Nebula, the Carina star forming region contains the large Carina OB1 association and several clusters, including numerous O-type stars and several Wolf-Rayet stars. Credits: NASA, ESA; Image processing by Judy Schmidt: Red: WFC3/UVIS F673N-F502N, Green: Pseudo, Blue: WFC3/UVIS F657N-F502N

Note from the Editor

The Star Formation Newsletter is now on the web at **www.starformation.news**. This PDF file contains the monthly Abstracts and links to the different Newsletter sections. Red text in this PDF is a url link. Submitting an abstract to the SFN is as simple as entering the arXiv ID (e.g., 2006.10139) in a web form on the SFN web site. **Do not remove the LATEX formatting when submitting to the arXiv**. If you do, your abstract will not look great either at the arXiv or the SFN.

Abstracts

1. Empirical Determination of the Lithium 6707.856 Å Wavelength in Young Stars

Justyn Campbell-White, Carlo F. Manara, Aurora Sicilia-Aguilar, Antonio Frasca, Louise D. Nielsen, P. Christian Schneider, Brunella Nisini, Amelia Bayo, Barbara Ercolano, Péter Ábrahám, Rik Claes, Min Fang, Davide Fedele, Jorge Filipe Gameiro, Manuele Gangi, Ágnes Kóspál, Karina Maucó, Monika G. Petr-Gotzens, Elisabetta Rigliaco, Connor Robinson, Michal Siwak, Lukasz Tychoniec, Laura Venuti ★ Absorption features in stellar atmospheres are often used to calibrate photocentric velocities for kinematic analysis of further spectral lines. The Li feature at ~ 6708 Å is commonly used, especially in the case of young stellar objects for which it is one of the strongest absorption lines. However, this is a complex line comprising two isotope fine-structure doublets. We empirically measure the wavelength of this Li feature in a sample of young stars from the PENELLOPE/VLT programme (using X-Shooter, UVES and ESPRESSO data) as well as HARPS data. For 51 targets, we fit 314 individual spectra using the STAR-MELT package, resulting in 241 accurately fitted Li features, given the automated goodness-of-fit threshold. We find the mean air wavelength to be 6707.856 Å, with a standard error of 0.002 Å (0.09 km/s) and a weighted standard deviation of 0.026 Å (1.16 km/s). The observed spread in measured positions spans 0.145 Å, or 6.5 km/s, which is up to a factor of six higher than typically reported velocity errors for high-resolution studies. We also find a correlation between the effective temperature of the star and the wavelength of the central absorption. We discuss how exclusively using this Li feature as a reference for photocentric velocity in young stars could potentially be introducing a systematic positive offset in wavelength to measurements of further spectral lines. If outflow tracing forbidden lines, such as [O i] 6300 Å, are actually more blueshifted than previously thought, this then favours a disk wind as the origin for such emission in young stars.

2. On the Origin of Dust Structures in Protoplanetary Disks: Constraints from the Rossby Wave Instability

Eonho Chang, Andrew N. Youdin, Leonardo Krapp ★ High resolution sub-mm observations of protoplanetary disks with ALMA have revealed that dust rings are common in large, bright disks. The leading explanation for these structures is dust-trapping in a local gas pressure maximum, caused by an embedded planet or other dynamical process. Independent of origin, such dust traps should be stable for many orbits to collect significant dust. However, ring-like perturbations in gas disks are also known to trigger the Rossby Wave Instability (RWI). We investigate whether axisymmetric pressure bumps can simultaneously trap dust and remain stable to the RWI. The answer depends on the thermodynamic properties of pressure bumps. For isothermal bumps, dust traps are RWI-stable for widths from $\sim$1 to several gas scale-heights. Adiabatic dust traps are stable over a smaller range of widths. For temperature bumps with no surface density component, however, all dust traps tend to be unstable. Smaller values of disk aspect ratio allow stable dust trapping at lower bump amplitudes and over a larger range of widths. We also report a new approximate criterion for RWI. Instability occurs when the radial oscillation frequency is $\lesssim 75\%$ of the Keplerian frequency, which differs from the well-known Lovelace necessary (but not sufficient) criterion for instability. Our results can guide ALMA observations of molecular gas by constraining the resolution and sensitivity needed to identify the pressure bumps thought to be responsible for dust rings.

3. Global N-body simulations of circumbinary planet formation around Kepler-16 and -34 analogues I: Exploring the pebble accretion scenario

Gavin A. L. Coleman, Richard P. Nelson, Amaury H. M. J. Triaud ★ Numerous circumbinary planets have been discovered in surveys of transiting planets. Often, these planets are found to orbit near to the zone of dynamical instability, close to the central binary. The existence of these planets has been explained by hydrodynamical simulations that show that migrating circumbinary planets, embedded in circumbinary discs, halt at the central cavity that is formed by the central binary. Transit surveys are naturally most sensitive to finding circumbinary planets with the shortest orbital periods. The future promise of detecting longer period systems using radial-velocity searches, combined with the anticipated detection of numerous circumbinary planets by ESA's PLATO mission, points to the need to model and understand the formation and evolution of circumbinary planets in a more general sense than has been considered before. With this goal in mind, we present a newly developed global model of circumbinary planet formation that is based on the mercury6 symplectic N-body integrator, combined with a model for the circumbinary disc and prescriptions for a range of processes involved in planet formation such as pebble accretion, gas envelope accretion and migration. Our results show that under reasonable assumptions, the pebble accretion scenario can produce circumbinary systems that are similar to those observed, and in particular is able to produce planets akin to Kepler-16b and Kepler-34b. Comparing our results to other systems, we find that our models also adequately reproduce such systems, including multi-planet systems. Resonances between neighbouring planets are frequently obtained, whilst ejections of planets by the central binary acts as an effective source of free floating planets.

4. Turbulence in Zeeman Measurements from Molecular Clouds

Zhuo Cao, Hua-bai Li ★ Magnetic fields (B-fields) play an important role in molecular cloud fragmentation and star formation, but are very difficult to detect. The temporal correlation between the field strength (B) and gas density (n) of an isolated cloud has been suggested as an indication of the dynamical importance of B-fields relative to self-gravity. This temporal B-n relation is, however, unobservable. What can be observed using Zeeman measurements are the "spatial B-n relations" from the current plane of the sky. Nevertheless, the temporal B-n relation argument has still been widely used to interpret observations. Here we present the first numerical test of the legitimacy of this interpretation. From a simulation that can reproduce the observed Zeeman spatial B $n^{2/3}$ relation, we found that temporal B-n relations of individual cores bear no resemblance to the spatial B-n relations. This result inspired us to discover that the true mechanism behind the 2/3 index is random turbulence compression instead of symmetrical gravitational contraction.

5. Membership analysis and 3D kinematics of the star-forming complex around Trumpler 37 using Gaia-DR3

Swagat R. Das, Saumya Gupta, Prem Prakash, Manash Samal, Jessy Jose ★ Identifying and characterizing young populations of star-forming regions is crucial to unravel their properties. In this regard, Gaia-DR3 data and machine learning tools are very useful for studying large star-forming complexes. In this work, we analyze the $\sim 7.1\text{degree}^2$ area of one of our Galaxy's dominant feedback-driven star-forming complexes, i.e., the region around Trumpler 37. Using the Gaussian mixture and random forest classifier methods, we identify 1243 high-probable members in the complex, of which $\sim 60\%$ are new members and are complete down to the mass limit of $\sim 0.1 - 0.2\ M_\odot$. The spatial distribution of the stars reveals multiple clusters towards the complex, where the central cluster around the massive star HD 206267 reveals two sub-clusters. Of the 1243 stars, 152 have radial velocity, with a mean value of -16.41 ± 0.72 km/s. We investigate stars' internal and relative movement within the central cluster. The kinematic analysis shows that the cluster's expansion is relatively slow compared to the whole complex. This slow expansion is possibly due to newly formed young stars within the cluster. We discuss these results in the context of hierarchical collapse and feedback-induced collapse mode of star formation in the complex.

6. Planetesimal growth in evolving protoplanetary disks: constraints from the pebble supply

Tong Fang, Hui Zhang, Shangfei Liu, Beibei Liu, Hongping Deng ★ In the core accretion model, planetesimals grow by mutual collisions and engulfing millimeter to centimeter particles, i.e., pebbles. Pebble accretion can significantly increase the accretion efficiency and help explain the presence of planets on wide orbits. However, the pebble supply is typically parameterized as a coherent pebble mass flux, sometimes being constant in space and time. Here we solve the dust advection and diffusion within viciously evolving protoplanetary disks to determine the pebble supply self-consistently. The pebbles are then accreted by planetesimals interacting with the gas disk via gas drags and gravitational torques. The pebble supply is variable with space and decays with time quickly with a pebble flux below 10 $M_\oplus$/Myr after 1 Myr in our models. As a result, only when massive planetesimals ($> 0.01\ M_\oplus$) are luckily produced by the streaming instability or the disk has low viscosity ($\alpha \sim 0.0001$), can the herd of planetesimals grows over Mars mass within 2 Myr. By then, planetesimals only capture pebbles about 50 times their mass and as little as 10 times beyond 20 au due to limited pebble supply. Further studies considering multiple dust species in various disk conditions are warranted to fully assess the realistic pebble supply and its influence on planetesimal growth.

7. MINDS. The detection of $^{13}CO_2$ with JWST-MIRI indicates abundant CO_2 in a protoplanetary disk

Sierra L. Grant et al. (MINDS Collaboration) ★ We present JWST-MIRI MRS spectra of the protoplanetary disk around the low-mass T Tauri star GW Lup from the MIRI mid-INfrared Disk Survey (MINDS) GTO program. Emission from $^{12}CO_2$, $^{13}CO_2$, H_2O, HCN, C_2H_2, and OH is identified with $^{13}CO_2$ being detected for the first time in a protoplanetary disk. We characterize the chemical and physical conditions in the inner few au of the GW Lup disk using these molecules as probes. The spectral resolution of JWST-MIRI MRS paired with high signal-to-noise data is essential to identify these species and determine their column densities and temperatures. The Q-branches of these molecules, including those of hot-bands, are particularly sensitive to temperature and column density. We find that the $^{12}CO_2$ emission in the GW Lup disk is coming from optically thick emission at a temperature of ∼400 K. $^{13}CO_2$ is optically thinner and based on a lower temperature of ∼325 K, may be tracing deeper into the disk and/or a larger emitting radius than $^{12}CO_2$. The derived N_{CO_2}/N_{H_2O} ratio is orders of magnitude higher than previously derived for GW Lup and other targets based on *Spitzer*-IRS data. This high column density ratio may be due to an inner cavity with a radius in between the H_2O and CO_2 snowlines and/or an overall lower disk temperature. This paper demonstrates the unique ability of JWST to probe inner disk structures and chemistry through weak, previously unseen molecular features.

8. What governs the spin distribution of very young < 1 Myr low mass stars

L. Gehrig, E. I. Vorobyov ★ We compute the evolution and rotational periods of young stars, using the MESA code, starting from a stellar seed, and take protostellar accretion, stellar winds, and the magnetic star-disk interaction into account. Furthermore, we add a certain fraction of the energy of accreted material into the stellar interior as additional heat and combine the resulting effects on stellar evolution with the stellar spin model. For different combinations of parameters, stellar periods at an age of 1 Myr range between 0.6 days and 12.9 days. Thus, during the relatively short time period of 1 Myr, a significant amount of stellar angular momentum can already be removed by the interaction between the star and its accretion disk. The amount of additional heat added into the stellar interior, the accretion history, and the presence of disk and stellar winds have the strongest impact on the stellar spin evolution during the first million years. The slowest stellar rotations result from a combination of strong magnetic fields, a large amount of additional heat, and effective winds. The fastest rotators combine weak magnetic fields and ineffective winds or result from a small amount of additional heat added to the star. Scenarios that could lead to such configurations are discussed. Different initial rotation periods of the stellar seed, on the other hand, quickly converges and do not affect the stellar period at all. Our model matches up to 90% of the observed rotation periods in six young ($\lesssim 3$ Myr) clusters. Based on these intriguing results, we motivate to combine our model with a hydrodynamic disk evolution code to self-consistently include several important aspects such as episodic accretion events, magnetic disk winds, internal, and external photo-evaporation. (Shortened)

9. Migration of pairs of giant planets in low-viscosity discs

P. Griveaud, A. Crida, E. Lega ★ When considering the migration of Jupiter and Saturn, a classical result is to find the planets migrating outwards and locked in the 3:2 mean motion resonance (MMR). These results were obtained in the framework of viscously accreting discs, in which the observed stellar accretion rates constrained the viscosity values. However, it has recently been shown observationally and theoretically that discs are probably less viscous than previously thought. Therefore, in this paper, we explore the dynamics of pairs of giant planets in low-viscosity discs. We performed two-dimensional hydrodynamical simulations using the grid-based code FARGOCA. In contrast to classical viscous discs, we find that the outer planet never crosses the 2:1 resonance and the pair does not migrate outwards. After a wide parameter exploration, including the mass of the outer planet, we find that the planets are primarily locked in the 2:1 MMR and in some cases in the 5:2 MMR. We explain semi-analytically why it is not possible for the outer planet to cross the 2:1 MMR in a low-viscosity disc. We find that pairs of giant planets migrate inwards in low-viscosity discs. Although, in some cases, having a pair of giant planets can slow down the migration speed with respect to a single planet. Such pairs of slowly migrating planets may be located, at the end of the disc phase, in the population of exoplanets of 'warm Jupiters'. However, the planets never migrate outwards. These results could have strong implications on the Solar System's formation scenarios if the Sun's protoplanetary disc had a low viscosity.

10. Physical conditions for dust grain alignment in Class 0 protostellar cores II. The role of the radiation field in models aligning/disrupting dust grains

Valentin J. M. Le Gouellec, Anaëlle J. Maury, Charles L. H. Hull, Antoine Verliat, Patrick Hennebelle, Valeska Valdivia ★ The polarized dust emission observed in Class 0 protostellar cores at high angular resolution with ALMA has raised several concerns about the grain alignment conditions in these regions. We aim to study the role of the radiation field on the grain alignment mechanisms occurring in the interior ($<$1000 au) of Class 0 protostars. We produce synthetic observations of the polarized dust emission from a MHD model of protostellar formation, using the POLARIS dust radiative transfer tool, which includes dust alignment with Radiative Torques Alignment (RATs). We test how the polarized dust emission from the model core depends on the irradiation conditions in the protostellar envelope, by varying the radiation due to accretion luminosity propagating from the central protostellar embryo throughout the envelope. The level of grain alignment efficiency obtained in the radiative transfer models is then compared to (sub-) millimeter ALMA dust polarization observations of Class 0 protostars. Our radiative transfer calculations have a central irradiation that reproduces the protostellar luminosities typically observed towards low- to intermediate-mass protostars, as well as super-paramagnetic grains, and grains $>$10 micron, which are required to bring the dust grain alignment efficiencies of the synthetic observations up to observed levels. Our radiative transfer calculations show that irradiation plays an important role in the mechanisms that dictate the size range of aligned grains in Class 0 protostars. Regions of the envelope that are preferentially irradiated harbor strong polarized dust emission but can be affected by the rotational disruption of dust grains. Episodes of high luminosity could affect grain alignment and trigger grain disruption mechanisms. [abridged]

11. GMC Collisions As Triggers of Star Formation. VIII. The Core Mass Function

Chia-Jung Hsu, Jonathan C. Tan, Duncan Christie, Yu Cheng, Theo J. O'Neill ★ Compression in giant molecular cloud (GMC) collisions is a promising mechanism to trigger formation of massive star clusters and OB associations. We simulate colliding and non-colliding magnetised GMCs and examine the properties of prestellar cores, selected from projected mass surface density maps, including after synthetic *ALMA* observations. We then examine core properties, including mass, size, density, velocity, velocity dispersion, temperature and magnetic field strength. After four Myr, $\sim 1,000$ cores have formed in the GMC collision and the high-mass end of the core mass function (CMF) can be fit by a power law $dN/d\log M \propto M^{-\alpha}$ with $\alpha \simeq 0.7$, i.e., relatively top-heavy compared to a Salpeter mass function. Depending on how cores are identified, a break in the power law can appear around a few $\times 10\,M_\odot$. The non-colliding GMCs form fewer cores with a CMF with $\alpha \simeq 0.8$ to 1.2, i.e., closer to the Salpeter index. We compare the properties of these CMFs to those of several observed samples of cores. Considering other properties, cores formed from colliding clouds are typically warmer, have more disturbed internal kinematics and are more likely to be gravitational unbound, than cores formed from non-colliding GMCs. The dynamical state of the protocluster of cores formed in the GMC-GMC collision is intrinsically subvirial, but can appear to be supervirial if the total mass measurement is affected by observations that miss mass on large scales or at low densities.

12. Crescent-Shaped Molecular Outflow from the Intermediate-mass Protostar DK Cha Revealed by ALMA

Naoto Harada, Kazuki Tokuda, Hayao Yamasaki, Asako Sato, Mitsuki Omura, Shingo Hirano, Toshikazu Onishi, Kengo Tachihara, Masahiro N. Machida ★ We report on an Atacama Large Millimeter/submillimeter Array (ALMA) study of the Class I or II intermediate-mass protostar DK Cha in the Chamaeleon II region. The 12CO (J=2-1) images have an angular resolution of 1" (250 au) and show high-velocity blueshifted (>70 km s-1) and redshifted (>50 km s-1) emissions which have 3000 au scale crescent-shaped structures around the protostellar disk traced in the 1.3mm continuum. Because the high-velocity components of the CO emission are associated with the protostar, we concluded that the emission traces the pole-on outflow. The blueshifted outflow lobe has a clear layered velocity gradient with a higher velocity component located on the inner side of the crescent shape, which can be explained by a model of an outflow with a higher velocity in the inner radii. Based on the directly driven outflow scenario, we estimated the driving radii from the observed outflow velocities and found that the driving region extends over two orders of magnitude. The 13CO emission traces a complex envelope structure with arc-like substructures with lengths of 1000au. We identified the arc-like structures as streamers because they appear to be connected to a rotating infalling envelope. DK Cha is useful for understanding characteristics that are visible by looking at nearly face-on configurations of young protostellar systems, providing an alternative perspective for studying the star-formation process.

13. Collisional evolution of dust and water ice in protoplanetary discs during and after an accretion outburst

Adrien Houge, Sebastiaan Krijt ★ Most protoplanetary discs are thought to undergo violent and frequent accretion outbursts, during which the accretion rate and central luminosity are elevated for several decades. This temporarily increases the disc temperature, leading to the sublimation of ice species as snowlines move outwards. In this paper, we investigate how an FUor-type accretion outburst alters the growth and appearance of dust aggregates at different locations in protoplanetary discs. We develop a model based on the Monte Carlo approach to simulate locally the coagulation and fragmentation of icy dust particles and investigate different designs for their structure and response to sublimation. Our main finding is that the evolution of dust grains located between the quiescent and outburst water snowlines is driven by significant changes in composition and porosity. The time required for the dust population to recover from the outburst and return to a coagulation/fragmentation equilibrium depends on the complex interplay of coagulation physics and outburst properties, and can take up to 4500 yr at 5 au. Pebble-sized particles, the building blocks of planetesimals, are either deprecated in water ice or completely destroyed, respectively resulting in drier planetesimals or halting their formation altogether. When accretion outbursts are frequent events, the dust can be far from collisional equilibrium for a significant fraction of time, offering opportunities to track past outbursts in discs at millimetre wavelengths. Our results highlight the importance of including accretion outbursts in models of dust coagulation and planet formation.

14. Magnetic fields in the Horsehead Nebula

Jihye Hwang, Kate Pattle, Harriet Parsons, Mallory Go, Jongsoo Kim ★ We present the first polarized dust emission measurements of the Horsehead Nebula, obtained using the POL-2 polarimeter on the Submillimetre Common-User Bolometer Array 2 (SCUBA-2) camera on the James Clerk Maxwell Telescope (JCMT). The Horsehead Nebula contains two sub-millimeter sources, a photodissociation region (PDR; SMM1) and a starless core (SMM2). We see well-ordered magnetic fields in both sources. We estimated plane-of-sky magnetic field strengths of 56±9 and 129±21 μG in SMM1 and SMM2, respectively, and obtained mass-to-flux ratios and Alfvén Mach numbers of less than 0.6, suggesting that the magnetic field can resist gravitational collapse and that magnetic pressure exceeds internal turbulent pressure in these sources. In SMM2, the kinetic and gravitational energies are comparable to one another, but less than the magnetic energy. We suggest a schematic view of the overall magnetic field structure in the Horsehead Nebula. Magnetic field lines in SMM1 appear have been compressed and reordered during the formation of the PDR, while the likely more-embedded SMM2 may have inherited its field from that of the pre-shock molecular cloud. The magnetic fields appear to currently play an important role in supporting both sources.

15. The enhanced YSO population in Serpens

Priya Hasan, Mudasir Raja, Md Saifuddin, S N Hasan ★ The Serpens Molecular Cloud is one of the most active sites of ongoing star formation at a distance of about 300 pc, and hence is very well-suited for studies of young low-mass stars and sub-stellar objects. In this paper, for the Serpens star forming region, we find potential members of the Young Stellar Objects population from the Gaia DR3 data and study their kinematics and distribution. We compile a catalog of 656 YSOs from available catalogs ranging from X-ray to the infrared. We use this as a reference set and cross-match it to find 87 Gaia DR3 member stars to produce a control sample with revised parameters. We queried the DR3 catalog with these parameters and found 1196 stars. We then applied three different density-based machine learning algorithms (DBSCAN, OPTICS and HDBSCAN) to this sample and found potential YSOs. The three clustering algorithms identified a common set of 822 YSO members from Gaia DR3 in this region. We also classified these objects using 2MASS and WISE data to study their distribution and the progress of star formation in Serpens.

16. Azimuthal C/O Variations in a Planet-Forming Disk

Luke Keyte, Mihkel Kama, Alice S. Booth, Edwin A. Bergin, L. Ilsedore Cleeves, Ewine F. van Dishoeck, Maria N. Drozdovskaya, Kenji Furuya, Jonathan Rawlings, Oliver Shorttle, Catherine Walsh ★ The elemental carbon-to-oxygen ratio (C/O) in the atmosphere of a giant planet is a promising diagnostic of that planet's formation history in a protoplanetary disk. Alongside efforts in the exoplanet community to measure C/O in planetary atmospheres, observational and theoretical studies of disks are increasingly focused on understanding how the gas-phase C/O varies both with radial location and between disks. This is mostly tied to the icelines of major volatile carriers such as CO and H2O. Using ALMA observations of CS and SO, we have unearthed evidence for an entirely novel type of C/O variation in the protoplanetary disk around HD 100546: an azimuthal variation from a typical, oxygen-dominated ratio (C/O=0.5) to a carbon-dominated ratio (C/O>1.0). We show that the spatial distribution and peculiar line kinematics of both CS and SO molecules can be well-explained by azimuthal variations in the C/O ratio. We propose a shadowing mechanism that could lead to such a chemical dichotomy. Our results imply that tracing the formation history of giant exoplanets using their atmospheric C/O ratios will need to take into account time-dependent azimuthal C/O variations in a planet's accretion zone.

17. Simulations of pre-supernova feedback in spherical clouds

Michalis Kourniotis, Richard Wünsch, Sergio Martínez-González, Jan Palouš, Guillermo Tenorio-Tagle, Soňa Ehlerová ★ We present a one-dimensional radiation-hydrodynamic model of a spherically symmetric cloud evolving under the influence of the self-gravity and the feedback from a star cluster forming in its centre. On one hand, the model is simple due to its 1D geometry, on the other hand, the feedback includes the ionising radiation, stellar winds and the radiation pressure acting on gas and dust. The star cluster is formed from the gas flowing into the cloud centre and the feedback parameters are determined from stellar evolution models and the cluster star forming history. The model is compared to the semi-analytic code WARPFIELD implementing similar physical processes and exploring the scenario that the young cluster R136 in the Large Magellanic Cloud was formed due to re-collapse of the shell formed by the previous generation star cluster. A good qualitative agreement is found, however, $3-4$ times higher stellar mass is needed to disrupt the cloud in our model, because it takes into account (contrary to WARPFIELD) self-gravity of the cloud surrounding the shell. We use the model to explore star formation in clouds with different mass, radius and density profile measuring their star formation efficiency (SFE), i.e. the fraction of the cloud mass converted to stars. We found that SFE is a function of a single parameter, $\log(\mathrm{SFE}) \propto -n_{hm}^{-0.46}$, with n_{hm} being the cloud mean particle density within its half-mass radius. Furthermore, we found that the feedback efficiency, i.e. a fraction of the feedback energy retained by gas, has a nearly constant value $\sim 10^{-3}$.

18. JWST/MIRI Spectroscopy of the Disk of the Young Eruptive Star EX Lup in Quiescence

Ágnes Kóspál, Péter Ábrahám, Lindsey Diehl, Andrea Banzatti, Jeroen Bouwman, Lei Chen, Fernando Cruz-Sáenz de Miera, Joel D. Green, Thomas Henning, Christian Rab ★ EX Lup is a low-mass pre-main sequence star that occasionally shows accretion-related outbursts. Here, we present JWST/MIRI medium resolution spectroscopy obtained for EX Lup fourteen years after its powerful outburst. EX Lup is now in quiescence and displays a Class II spectrum. We detect a forest of emission lines from molecules previously identified in infrared spectra of classical T Tauri disks: H2O, OH, H2, HCN, C2H2, and CO2. The detection of organic molecules demonstrates that they are back after disappearing during the large outburst. Spectral lines from water and OH are for the first time de-blended and will provide a much improved characterization of their distribution and density in the inner disk. The spectrum also shows broad emission bands from warm, sub-micron size amorphous silicate grains at 10 and 18 um. During the outburst, in 2008, crystalline forsterite grains were annealed in the inner disk within 1 au, but their spectral signatures in the 10 um silicate band later disappeared. With JWST we re-discovered these crystals via their 19.0, 20.0, and 23.5 um emission, whose strength implies that the particles are at 3 au from the star. This suggests that crystalline grains formed in 2008 were transported outwards and now approach the water snowline, where they may be incorporated into planetesimals. Containing several key tracers of planetesimal and planet formation, EX Lup is an ideal laboratory to study the effects of variable luminosity on the planet-forming material and may provide explanation for the observed high crystalline fraction in solar system comets.

19. Measurement of the angular momenta of pre-main-sequence stars: early evolution of slow and fast rotators and empirical constraints on spin-down torque mechanisms

Marina Kounkel, Keivan G. Stassun, Lynne A. Hillenbrand, Jesús Hernández, Javier Serna, Jason Lee Curtis ★ We use TESS full-frame imaging data to investigate the angular momentum evolution of young stars in Orion Complex. We confirm recent findings that stars with rotation periods faster than 2 d are overwhelmingly binaries, with typical separations of tens of AU; such binaries quickly clear their disks, leading to a tendency for rapid rotators to be diskless. Among (nominally single) stars with rotation periods slower than 2 d, we observe the familiar, gyrochronological horseshoe-shaped relationship of rotation period versus $T_{\rm eff}$, indicating that the processes which govern the universal evolution of stellar rotation on Gyr timescales are already in place within the first few Myr. Using spectroscopic $v \sin i$ we determine the distribution of $\sin i$, revealing that the youngest stars are biased toward more pole-on orientations, which may be responsible for the systematics between stellar mass and age observed in star-forming regions. We are also able for the first time to make empirical, quantitative measurements of angular momenta and their time derivative as functions of stellar mass and age, finding these relationships to be much simpler and monotonic as compared to the complex relationships involving rotation period alone; evidently, the relationship between rotation period and $T_{\rm eff}$ is largely a reflection of mass-dependent stellar structure and not of angular momentum per se. Our measurements show that the stars experience spin-down torques in the range 10^{37} erg at 1 Myr to 10^{35} erg at 10 Myr, which provide a crucial empirical touchstone for theoretical mechanisms of angular momentum loss in young stars.

20. Rejuvenating infall: a crucial yet overlooked source of mass and angular momentum

M. Kuffmeier, S. S. Jensen, T. Haugbølle ★ MHD models and the observation of accretion streamers confirmed that protostars can undergo late accretion events after the initial collapse phase. To provide better constraints, we study the evolution of stellar masses in MHD simulations of a $(4\ {\rm pc})^3$ molecular cloud. Tracer particles allow us to accurately follow the trajectory of accreting material for all protostars and thereby constrain the accretion reservoir of the stars. The diversity of the accretion process implies that stars in the solar mass regime can have vastly different accretion histories. Some stars accrete most of their mass during the initial collapse phase, while others gain >50 % of their final mass from late infall. The angular momentum budget of stars that experience substantial infall, so-called late accretors, is significantly higher than for stars without or with only little late accretion. As the probability of late infall increases with increasing final stellar mass, the specific angular momentum budget of higher mass stars is on average higher. The hypothetical centrifugal radius computed from the accreting particles at the time of formation is orders of magnitude higher than observed disk sizes, which emphasizes the importance of angular momentum transport during disk formation. Nevertheless, we find a correlation that the centrifugal radius is highest for stars with substantial infall, which suggests that very large disks are the result of recent infall events. There are also indications for a subtle trend of increasing centrifugal radius with increasing final stellar mass, which is in agreement with an observed marginal correlation of disk size and stellar mass. Finally, we show that late accretors become embedded again during infall. As a consequence, late accretors are (apparently) rejuvenated and would be classified as Class 0 objects according to their bolometric temperature despite being 1 Myr old.

21. On the 3D Curvature and Dynamics of the Musca filament

Aidan Kaminsky, Lars Bonne, Doris Arzoumanian, Simon Coudé ★ Filaments are ubiquitous in the interstellar medium (ISM), yet their formation and evolution remains the topic of intense debate. In order to obtain a more comprehensive view of the 3D morphology and evolution of the Musca filament, we model the $C^{18}O(2\text{-}1)$ emission along the filament crest with several large-scale velocity field structures. This indicates that Musca is well described by a 3D curved cylindrical filament with longitudinal mass inflow to the center of the filament unless the filament is a transient structure with a lifetime $\lesssim 0.1$ Myr. Gravitational longitudinal collapse models of filaments appear unable to explain the observed velocity field. To better understand these kinematics, we further analyze a map of the $C^{18}O$(2-1) velocity field at the location of SOFIA HAWC+ dust polarization observations that trace the magnetic field in the filament. This unveils an organized magnetic field that is oriented roughly perpendicular to the filament crest. Although the velocity field is also organized, it progressively changes its orientation by more than 90^o when laterally crossing the filament crest and thus appears disconnected from the magnetic field in the filament. This strong lateral change of the velocity field over the filament remains unexplained and might be associated with important longitudinal motion in the filament that can be associated to the large-scale kinematics along the filament.

22. Modelling Star Cluster Formation: Gas Accretion

Jeremy Karam, Alison Sills ★ The formation of star clusters involves the growth of smaller, gas-rich subclusters through accretion of gas from the giant molecular cloud within which the subclusters are embedded. The two main accretion mechanisms responsible for this are accretion of gas from dense filaments, and from the ambient background of the cloud. We perform simulations of both of these accretion processes onto gas-rich star clusters using coupled smoothed particle hydrodynamics to model the gas, and N-body dynamics to model the stars. We find that, for both accretion processes, the accreting star cluster loses some of its original mass while gaining mass from either the ambient background or the dense filament. The amount of mass lost from both these processes is small compared to the total mass of the cluster. However, in the case of accretion from a background medium, the net effect can be a decrease in the total mass of the cluster if it is travelling fast enough through the ambient medium (> 4kms^{-1}). We find that the amount of mass lost from the cluster through filamentary accretion is independent of the density, width, or number of filaments funneling gas into the cluster and is always such that the mass of the cluster is constantly increasing with time. We compare our results to idealized prescriptions used to model star cluster formation in larger scale GMC simulations and find that such prescriptions act as an upper limit when describing the mass of the star cluster they represent.

23. The first stars: formation, properties, and impact

Ralf S. Klessen, Simon C. O. Glover ★ The first generation of stars, often called Population III (or Pop III), form from metal-free primordial gas at redshifts 30 and below. They dominate the cosmic star formation history until redshifts 15 to 20, at which point the formation of metal-enriched Pop II stars takes over. We review current theoretical models for the formation, properties and impact of Pop III stars, and discuss existing and future observational constraints. Key takeaways from this review include the following: (1) Primordial gas is highly susceptible to fragmentation and Pop III stars form as members of small clusters with a logarithmically flat mass function. (2) Feedback from massive Pop III stars plays a central role in regulating subsequent star formation, but major uncertainties remain regarding its immediate impact. (3) In extreme conditions, supermassive Pop III stars can form, reaching masses of several 10^5 Msun. Their remnants may be the seeds of the supermassive black holes observed in high-redshift quasars. (4) Direct observations of Pop III stars in the early Universe remain extremely challenging. Indirect constraints from the global 21cm signal or gravitational waves are more promising. (5) Stellar archeological surveys allow us to constrain both the low-mass and the high-mass ends of the Pop III mass distribution. Observations suggest that most massive Pop III stars end their lives as core-collapse supernovae rather than as pair-instability supernovae.

24. A major asymmetric ice trap in a planet-forming disk IV. Nitric oxide gas and a lack of CN tracing sublimating ices and a C/O ratio < 1

M. Leemker, A. S. Booth, E. F. van Dishoeck, N. van der Marel, B. Tabone, N. F. W. Ligterink, N. G. C. Brunken, M. R. Hogerheijde ★ [Abridged] Most well-resolved disks observed with ALMA show signs of dust traps. These dust traps set the chemical composition of the planet forming material in these disks, as the dust grains with their icy mantles are trapped at specific radii and could deplete the gas and dust of volatiles at smaller radii. In this work we analyse the first detection of nitric oxide (NO) in a protoplanetary disk. We aim to constrain the nitrogen chemistry and the gas-phase C/O ratio in the highly asymmetric dust trap in the Oph-IRS 48 disk. We use ALMA observations of NO, CN, C_2H, and related molecules and model the effect of the dust trap on the physical and chemical structure using the thermochemical code DALI. Furthermore, we explore how ice sublimation contributes to the observed emission lines. NO is only observed at the location of the dust trap but CN and C_2H are not detected in the Oph-IRS 48 disk. This results in an CN/NO column density ratio of < 0.05 and thus a low C/O ratio at the location of the dust trap. The main gas-phase formation pathways to NO through OH and NH in the fiducial model predict NO emission that is an order of magnitude lower than is observed. The gaseous NO column density can be increased by factors ranging from 2.8 to 10 when the H_2O and NH_3 gas abundances are significantly boosted by ice sublimation. However, these models are inconsistent with the upper limits on the H_2O and OH column densities derived from observations. We propose that the NO emission in the Oph-IRS 48 disk is closely related to the nitrogen containing ices sublimating in the dust trap. The non-detection of CN constrains the C/O ratio both inside and outside the dust trap to be < 1 if all nitrogen initially starts as N_2 and ≤ 0.6, consistent with the Solar value, if (part of) the nitrogen initially starts as N or NH_3.

25. Multi-scale velocity statistics in NGC 6334: deviation from a continuous and universal turbulence cascade due to massive star formation activity

Junhao Liu, Qizhou Zhang, Hauyu Baobab Liu, Keping Qiu, Shanghuo Li, Zhi-Yun Li, Paul T. P. Ho, Josep Miquel Girart, Tao-Chung Ching, Huei-Ru Vivien Chen, Shih-Ping Lai, Ramprasad Rao, Ya-wen Tang ★ We use molecular line data from ALMA, SMA, JCMT, and NANTEN2 to study the multi-scale ($\sim$15-0.005 pc) velocity statistics in the massive star formation region NGC 6334. We find that the non-thermal motions revealed by the velocity dispersion function (VDF) stay supersonic over scales of several orders of magnitudes. The multi-scale non-thermal motions revealed by different instruments do not follow the same continuous power-law, which is because the massive star formation activities near central young stellar objects have increased the non-thermal motions in small-scale and high-density regions. The magnitudes of VDFs vary in different gas materials at the same scale, where the infrared dark clump N6334S in an early evolutionary stage shows a lower level of non-thermal motions than other more evolved clumps due to its more quiescent star formation activity. We find possible signs of small-scale-driven (e.g., by gravitational accretion or outflows) supersonic turbulence in clump N6334IV with a three-point VDF analysis. Our results clearly show that the scaling relation of velocity fields in NGC 6334 deviates from a continuous and universal turbulence cascade due to massive star formation activities.

26. Turbulent processing of PAHs in protoplanetary discs – Coagulation and freeze-out leading to depletion of gas-phase PAH

K. Lange, C. Dominik, A. G. G. M. Tielens ★ Polycyclic aromatic hydrocarbons (PAHs) have been detected in numerous circumstellar discs. We propose the continuous processing of PAHs through clustering, adsorption on dust grains, and their reverse-processes as key mechanisms to reduce the emission-capable PAH abundance in protoplanetary discs. This cycle of processing is driven by vertical turbulence in the disc mixing PAHs between the disc midplane and the photosphere. We used a theoretical Monte Carlo model for photodesorption and a coagulation code in the disc midplane to estimate the relevance and timescale of these processes in a Herbig Ae/Be disc environment. By combining these components in a 1D vertical model, we calculated the gas-phase depletion of PAHs that stick as clusters on dust grains. Our results show that the clustering of gas-phase PAHs is very efficient, and that clusters with more than 100 monomers can grow for years before they are able to freeze out in the disc midplane. Once a PAH cluster is frozen on the dust grain surface, the large heat capacity of these clusters prevents them from evaporating off the grains in UV-rich environments such as the photosphere. Therefore, the clustering of PAHs followed by freeze-out can lead to a depletion of gas-phase PAHs in discs. Evaluated over the lifetime of protoplanetary discs, we find a depletion of PAHs by a factor that ranges between 50 and 1000 compared to the standard ISM abundance of PAHs in the inner disc through turbulent processing. Through these processes, we favour PAHs smaller than circumovalene as the major gas-phase emitters of the disc photosphere as larger PAH monomers cannot photodesorb from the grain surface. These gas-phase PAHs co-exist with large PAH clusters sticking on dust grains. We find a close relation between the amount of PAHs frozen out on dust grains and the dust population, as well as the strength of the vertical turbulence.

27. Revealing magnetic field structure at the surfaces of protoplanetary disks via near-infrared circular polarization

Ilse de Langen, Ryo Tazaki ★ Context. Magnetic fields play a fundamental role in the dynamical evolution of protoplanetary disks, in particular via magnetically induced disk winds. The magnetic field structure at the disk surface is crucial for driving the disk winds; however, it is still poorly understood observationally. Aims. We explore a new method to probe the magnetic field structure at the disk surface using near-infrared (NIR) circular polarization. Near-infrared circular polarization arises when unpolarized stellar light is scattered by magnetically aligned grains at the disk surface. In this study, we aim to clarify to what extent the observed circular polarization pattern can be used to diagnose the magnetic field structure. Methods. We first calculated light scattering properties of aligned spheroids, and the results were then used to create expected observational images of the degree of circular polarization at a NIR wavelength. Results. Magnetically aligned grains can produce circular polarization, particularly when the field configuration deviates from a purely toroidal field. We find that disk azimuthal dependence of the degree of circular polarization tends to exhibit a double peaked profile when the field structure is favorable for driving disk winds by centrifugal force. We also find that even if the disk is spatially unresolved, a net circular polarization can possibly be nonzero. We also show that the amplitude of circular polarization is strongly dependent on grain composition and axis ratio. Conclusions. Our results suggest that circular polarization observations would be useful to study the magnetic field structure and dust properties at the disk surface.

28. FUors, EXors and the role of intermediate objects

T. Yu. Magakian, T. A. Movsessian, H. R. Andreasyan ★ The studies of FUors, EXors and other young eruptive stars are very important for the understanding of the earliest stages of pre-main-sequence evolution. We describe the current situation in this field. This is the short version of the review, presented in "Non-stationary processes in the protoplanetary disks and their observational manifestations" conference, Crimean Astrophysical Observatory

29. Outflows Driven by Direct and Reprocessed Radiation Pressure in Massive Star Clusters

Shyam H. Menon, Christoph Federrath, Mark R. Krumholz ★ We use three-dimensional radiation hydrodynamic (RHD) simulations to study the formation of massive star clusters under the combined effects of direct ultraviolet (UV) and dust-reprocessed infrared (IR) radiation pressure. We explore a broad range of mass surface density $\Sigma \sim 10^2$-$10^5\,\mathrm{M_\odot\,pc^{-2}}$, spanning values typical of weakly star-forming galaxies to extreme systems such as clouds forming super-star clusters, where radiation pressure is expected to be the dominant feedback mechanism. We find that star formation can only be regulated by radiation pressure for $\Sigma \lesssim 10^3\,\mathrm{M_\odot\,pc^{-2}}$, but that clouds with $\Sigma \lesssim 10^5\,\mathrm{M_\odot\,pc^{-2}}$ become super-Eddington once high star formation efficiencies ($\sim 80\%$) are reached, and therefore launch the remaining gas in a steady outflow. These outflows achieve mass-weighted radial velocities of ~ 15 - $30\,\mathrm{km\,s^{-1}}$, which is ~ 0.5 - 2.0 times the cloud escape speed. This suggests that radiation pressure is a strong candidate to explain recently observed molecular outflows found in young super-star clusters in nearby starburst galaxies. We quantify the relative importance of UV and IR radiation pressure in different regimes, and deduce that both are equally important for $\Sigma \sim 10^3\,\mathrm{M_\odot\,pc^{-2}}$, whereas clouds with higher (lower) density are increasingly dominated by the IR (UV) component. Comparison with control runs without either the UV or IR bands suggests that the outflows are primarily driven by the impulse provided by the UV component, while IR radiation has the effect of rendering a larger fraction of gas super-Eddington, and thereby increasing the outflow mass flux by a factor of ~ 2.

30. Relative Alignment Between Magnetic Fields and Molecular Gas Structure in Molecular Clouds

Renato Mazzei, Zhi-Yun Li, Che-Yu Chen, Laura Fissel, Mike Chen, James Park ★ We compare the structure of synthetic dust polarization with synthetic molecular line emission from radiative transfer calculations using a 3-dimensional, turbulent collapsing-cloud magnetohydrodynamics simulation. The histogram of relative orientations (HRO) technique and the projected Rayleigh statistic (PRS) are considered. In our trans-Alfvénic (more strongly magnetized) simulation, there is a transition to perpendicular alignment at densities above $\sim 4 \times 10^3$ cm^{-3}. This transition is recovered in most of our synthetic observations of optically thin molecular tracers, however for ^{12}CO it does not occur and the PRS remains in parallel alignment across the whole observer-space. We calculate the physical depth of the optical depth $\tau = 1$ surface and find that for ^{12}CO it is largely located in front of the cloud midplane, suggesting that ^{12}CO is too optically thick and instead mainly probes low volume density gas. In our super-Alfvénic simulation, the magnetic field becomes significantly more tangled, and all observed tracers tend toward no preference for perpendicular or parallel alignment. An observable difference in alignment between optically thin and optically thick tracers may indicate the presence of a dynamically important magnetic field, though there is some degeneracy with viewing angle. We convolve our data with a Gaussian beam and compare it with HRO results of the Vela C molecular cloud. We find good agreement between these results and our sub-Alfvénic simulations when viewed with the magnetic field in the plane-of-the-sky (especially when sensitivity limitations are considered), though the observations are also consistent with an intermediately inclined magnetic field.

31. Herbig-Haro Flows and Young Stars in the Dobashi 5006 Dark Cloud

T. A. Movsessian, T. Yu. Magakian, A. S. Rastorguev, H. R. Andreasyan ★ Two new Herbig-Haro flows were found in a study of the isolated Dobashi 5006 dark cloud (l= 216°.7, b= −13°.9): one certain (HH 1179) and one presumable, associated with the infrared sources 2MASS 06082284−0936139 and 2MASS 06081525−0933490, correspondingly. Judging from their spectral energy distributions, these sources may be Class 1 objects with luminosities of order 23 $L_\odot$ and 3.6 $L_\odot$, respectively. They are part of the poor star cluster MWSC 0739, study of which based on data from the Gaia DR3 survey has made it possible to detect 17 stars which are probably members of it. A list of them and their main parameters is given. The distance of the cluster is estimated to be 820 pc and the color excess on the path to the cluster is E(BP-RP) ≈1.05 mag. All of these stars are PMS-objects and most of them are optically variable. It is concluded that the newly discovered compact star-formation zone in the Dobashi 5006 cloud has an age of no more than a few million years and this process continues up to the present time.

32. The role of magnetic fields in the formation of multiple massive stars

R. Mignon-Risse, M. González, B. Commerçon ★ (Abridged) Context. Most massive stars are located in multiple stellar systems. Magnetic fields are believed to be essential in the accretion and ejection processes around single massive protostars. Aims. Our aim is to unveil the influence of magnetic fields in the formation of multiple massive stars, in particular on the fragmentation modes and properties of the multiple protostellar system. Methods. Using RAMSES, we follow the collapse of a massive pre-stellar core with (non-ideal) radiation-(magneto-)hydrodynamics. We choose a setup which promotes multiple stellar system formation. Results. In the purely hydrodynamical models, we always obtain (at least) binary systems. When more than two stars are present, their gravitational interaction triggers mergers until there are two stars left. The following gas accretion increases their orbital separation and hierarchical fragmentation occurs so that both stars host a comparable disk and stellar system which then form similar disks as well. We identify several modes of fragmentation: Toomre-unstable disk fragmentation, arm-arm collision and arm-filament collision. Disks grow in size until they fragment and become truncated as the newly-formed companion gains mass. When including magnetic fields, the picture evolves: the primary disk produces less fragments, arm-filament collision is absent. Magnetic fields reduce the initial orbital separation but do not affect its further evolution, which is mainly driven by gas accretion. With magnetic fields, the growth of individual disks is regulated even in the absence of fragmentation or truncation. Conclusions. Hierarchical fragmentation is seen in unmagnetized and magnetized models. Magnetic fields, including non-ideal effects, are important because they remove certain fragmentation modes and limit the growth of disks, which is otherwise only limited through fragmentation.

33. VISIONS: The VISTA Star Formation Atlas – I. Survey overview

Stefan Meingast, João Alves, Hervé Bouy, Monika G. Petr-Gotzens, Verena Fürnkranz, Josefa E. Großschedl, David Hernandez, Alena Rottensteiner, Magda Arnaboldi, Joana Ascenso, Amelia Bayo, Erik Brändli, Anthony G. A. Brown, Jan Forbrich, Alyssa Goodman, Alvaro Hacar, Birgit Hasenberger, Rainer Köhler, Karolina Kubiak, Michael Kuhn, Charles Lada, Kieran Leschinski, Marco Lombardi, Diego Mardones, Laura Mascetti, Núria Miret-Roig, André Moitinho, Koraljka Mužic, Martin Piecka, Laura Posch, Timo Prusti, Karla Peña Ramírez, Ronny Ramlau, Sebastian Ratzenböck, Germano Sacco, Cameren Swiggum, Paula Stella Teixeira, Vanessa Urban, Eleonora Zari, Catherine Zucker ★ VISIONS is an ESO public survey of five nearby (d $<$ 500 pc) star-forming molecular cloud complexes that are canonically associated with the constellations of Chamaeleon, Corona Australis, Lupus, Ophiuchus, and Orion. The survey was carried out with VISTA, using VIRCAM, and collected data in the near-infrared passbands J, H, and Ks. With a total on-sky exposure time of 49.4 h VISIONS covers an area of 650 deg^2, and it was designed to build an infrared legacy archive similar to that of 2MASS. Taking place between April 2017 and March 2022, the observations yielded approximately 1.15 million images, which comprise 19 TB of raw data. The observations are grouped into three different subsurveys: The wide subsurvey comprises shallow, large-scale observations and has visited the star-forming complexes six times over the course of its execution. The deep subsurvey of dedicated high-sensitivity observations has collected data on the areas with the largest amounts of dust extinction. The control subsurvey includes observations of areas of low-to-negligible dust extinction. Using this strategy, the VISIONS survey offers multi-epoch position measurements, is able to access deeply embedded objects, and provides a baseline for statistical comparisons and sample completeness. In particular, VISIONS is designed to measure the proper motions of point sources with a precision of 1 mas/yr or better, when complemented with data from VHS. Hence, VISIONS can provide proper motions for sources inaccessible to Gaia. VISIONS will enable addressing a range of topics, including the 3D distribution and motion of embedded stars and the nearby interstellar medium, the identification and characterization of young stellar objects, the formation and evolution of embedded stellar clusters and their initial mass function, as well as the characteristics of interstellar dust and the reddening law.

34. VISIONS: The VISTA Star Formation Atlas – II. The data processing pipeline

Stefan Meingast, Hervé Bouy, Verena Fürnkranz, David Hernandez, Alena Rottensteiner, Erik Brändli ★ The VISIONS public survey provides large-scale, multiepoch imaging of five nearby star-forming regions at subarcsecond resolution in the near-infrared. All data collected within the program and provided by the European Southern Observatory (ESO) science archive are processed with a custom end-to-end pipeline infrastructure to provide science-ready images and source catalogs. The data reduction environment has been specifically developed for the purpose of mitigating several shortcomings of the bona fide data products processed with software provided by the Cambridge Astronomical Survey Unit (CASU), such as spatially variable astrometric and photometric biases of up to 100 mas and 0.1 mag, respectively. At the same time, the resolution of coadded images is up to 20% higher compared to the same products from the CASU processing environment. Most pipeline modules are written in Python and make extensive use of C extension libraries for numeric computations, thereby simultaneously providing accessibility, robustness, and high performance. The astrometric calibration is performed relative to the Gaia reference frame, and fluxes are calibrated with respect to the source magnitudes provided in the Two Micron All Sky Survey (2MASS). For bright sources, absolute astrometric errors are typically on the order of 10 to 15 mas and fluxes are determined with subpercent precision. Moreover, the calibration with respect to 2MASS photometry is largely free of color terms. The pipeline produces data that are compliant with the ESO Phase 3 regulations and furthermore provides curated source catalogs that are structured similarly to those provided by the 2MASS survey.

35. The parallax and 3D kinematics of water masers in the massive star-forming region G034.43+0.24

Xiaofeng Mai, Bo Zhang, M. J. Reid, L. Moscadelli, Shuangjing Xu, Yan Sun, Jingdong Zhang, Wen Chen, Shiming Wen, Qiuyi Luo, Karl M. Menten, Xingwu Zheng, Andreas Brunthaler, Ye Xu, Guangli Wang ★ We report a trigonometric parallax measurement of 22 GHz water masers in the massive star-forming region G034.43+0.24 as part of the Bar and Spiral Structure Legacy (BeSSeL) Survey using the Very Long Baseline Array. The parallax is 0.330±50.018 mas, corresponding to a distance of $3.03^{+0.17}_{-0.16}$ kpc. This locates G034.43+0.24 near the inner edge of the Sagittarius spiral arm and at one end of a linear distribution of massive young stars which cross nearly the full width of the arm. The measured 3-dimensional motion of G034.43+0.24 indicates a near-circular Galactic orbit. The water masers display arc-like distributions, possibly bow shocks, associated with winds from one or more massive young stars.

36. Igneous Rim Accretion on Chondrules in Low-Velocity Shock Waves

Yuji Matsumoto, Sota Arakawa ★ Shock wave heating is a leading candidate for the mechanisms of chondrule formation. This mechanism forms chondrules when the shock velocity is in a certain range. If the shock velocity is lower than this range, dust particles smaller than chondrule precursors melt, while chondrule precursors do not. We focus on the low-velocity shock waves as the igneous rim accretion events. Using a semi-analytical treatment of the shock-wave heating model, we found that the accretion of molten dust particles occurs when they are supercooling. The accreted igneous rims have two layers, which are the layers of the accreted supercooled droplets and crystallized dust particles. We suggest that chondrules experience multiple rim-forming shock events.

37. Processing of hydroxylamine, NH2OH, an important prebiotic precursor, on interstellar ices

Gerán Molpeceres, Víctor. M. Rivilla, Kenji Furuya, Johannes Kästner, Belén Maté, Yuri Aikawa ★ Hydroxylamine, NH2OH, is one of the already detected interstellar molecules with the highest prebiotic potential. Yet, the abundance of this molecule found by astronomical observations is rather low for a relatively simple molecule, $\sim 10^{-10}$ relative to H2. This seemingly low abundance can be rationalized by destruction routes operating on interstellar dust grains. In this work, we tested the viability of this hypothesis under several prisms, finding that the origin of a lower abundance of NH2OH can be explained by two chemical processes, one operating at low temperature (10 K) and the other at intermediate temperature (20 K). At low temperatures, enabling the hydrogen abstraction reaction HNO + H -> NO + H2, even in small amounts, partially inhibits the formation of NH2OH through successive hydrogenation of NO, and reduces its abundance on the grains. We found that enabling a 15–30% of binding sites for this reaction results in reductions of NH2OH abundance of ∼ 1-2 orders of magnitude. At warmer temperatures (20 K, in our study), the reaction NH2OH + H -> HNOH + H2, which was found to be fast ($k \sim 10^6$ s^{-1}) in this work, followed by further abstractions by adsorbates that are immobile at 10 K (O, N) are the main route of NH2OH destruction. Our results shed light on the abundance of hydroxylamine in space and pave the way to constraining the subsequent chemistry experienced by this molecule and its derivatives in the interstellar prebiotic chemistry canvas.

38. Misalignment of the outer disk of DK Tau and a first look at its magnetic field using spectropolarimetry

M. Nelissen, P. McGinnis, C. P. Folsom, T. Ray, A. A. Vidotto, E. Alecian, J. Bouvier, J. Morin, J. -F. Donati, R. Devaraj ★ Misalignments between a forming star's rotation axis and its outer disk axis, although not predicted by standard theories of stellar formation, have been observed in several classical T Tauri stars (cTTs). The low-mass cTTs DK Tau is suspected of being among them. It is also an excellent subject to investigate the interaction between stellar magnetic fields and material accreting from the circumstellar disk, as it presents clear signatures of accretion. The goal of this paper is to study DK Tau's average line-of-sight magnetic field (Blos) in both photospheric absorption lines and emission lines linked to accretion, using spectropolarimetric observations, as well as to examine inconsistencies regarding its rotation axis. We used data collected with the ESPaDOnS and NARVAL spectropolarimeters, probing two distinct epochs (2010 and 2012). We first determined the stellar parameters, such as effective temperature and v sin i. Next, we removed the effect of veiling from the spectra, then obtained least-squares deconvolution profiles of the absorption lines, before determining the Blos. We also investigated emission lines, the 587.6 nm HeI line and the CaII infrared triplet, as tracers of the magnetic fields present in the accretion shocks. We find that DK Tau experiences accretion onto a magnetic pole at an angle of about 30 degrees from the pole of its rotation axis, with a positive field at the base of the accretion funnels. In 2010 we find a magnetic field of up to 1.77kG, and in 2012 up to 1.99kG. Additionally, using our derived values of period, v sin i and stellar radius, we find a value of 58 degrees (+18)(-11) for the inclination of the stellar rotation axis, which is significantly different from the outer disk axis inclination of 21 degrees given in the literature. We find that DK Tau's outer disk axis is likely misaligned compared to its rotation axis by 37 degrees.

39. Gaia colour-magnitude diagrams of young open clusters: Identification in the UBC catalogue and a comparison of manual and automated analysis

Ignacio Negueruela, Abel de Burgos ★ Automated analysis of Gaia astrometric data has led to the discovery of many new high-quality open cluster candidates. With a good determination of their parameters, these objects become excellent tools to investigate the properties of our Galaxy. We explore whether young open clusters can be readily identified from Gaia data alone by studying the properties of their Gaia colour-magnitude diagrams. We also want to compare the results of a traditional cluster analysis with those of automated methods. We selected three young open cluster candidates from the UBC catalogue, ranging from a well-populated object with a well-defined sequence to a poorly-populated, poorly-defined candidate. We obtained classification spectra for the brightest stars in each. We redetermined members based on EDR3 data and fitted isochrones to derive age, distance and reddening. All three candidates are real clusters with age below 100 Ma. UBC103 is a moderately populous cluster, with an age around 70 Ma. At a distance of ∼ 3 kpc, it forms a binary cluster with the nearby NGC6683. UBC114 is a relatively nearby (∼ 1.5kpc) poorly-populated cluster containing two early-B stars. UBC587 is a dispersed, very young (< 10 Ma) cluster located at ∼ 3 kpc, behind the Cygnus X region, and may be a valuable tracer of the Orion arm. The OCfinder methodology for the identification of new open clusters is extremely successful, with even poor candidates resulting in interesting detections. The presence of an almost vertical photometric sequence in the Gaia colour-magnitude diagram is a safe way to identify young open clusters. Automated methods for the determination of cluster properties give approximate solutions, but are still subject to some difficulties. There is some evidence suggesting that artificial intelligence systems may systematically underestimate extinction, which may impact in the age determination.

40. Rubin LSST observing strategies to maximize volume and uniformity coverage of Star Forming Regions in the Galactic Plane

L. Prisinzano, R. Bonito, A. Mazzi, F. Damiani, S. Ustamujic, P. Yoachim, R. Street, M. G. Guarcello, L. Venuti, W. Clarkson, L. Jones, L. Girardi ★ A complete map of the youngest stellar populations of the Milky Way in the era of all-sky surveys, is one of the most challenging goals in modern astrophysics. The characterisation of the youngest stellar component is crucial not only for a global overview of the Milky Way structure, of the Galactic thin disk, and its spiral arms, but also for local studies. In fact, the identification of the star forming regions (SFRs) and the comparison with the environment in which they form are also fundamental to put them in the context of the surrounding giant molecular clouds and to understand still unknown physical mechanisms related to the star and planet formation processes. In 10 yrs of observations, Vera C. Rubin Legacy Survey of Space and Time (Rubin-LSST) will achieve an exquisite photometric depth that will allow us to significantly extend the volume within which we will be able to discover new SFRs and to enlarge the domain of a detailed knowledge of our own Galaxy. We describe here a metrics that estimates the total number of young stars with ages t $<$ 10 Myr and masses $>0.3M_\odot$ that will be detected with the Rubin LSST observations in the gri bands at a 5 σ magnitude significance. We examine the results of our metrics adopting the most recent simulated Rubin-LSST survey strategies in order to evaluate the impact that different observing strategies might have on our science case.

41. Short-lived radioisotope enrichment in star-forming regions from stellar winds and supernovae

Richard J. Parker, Tim Lichtenberg, Miti Patel, Cheyenne K. M. Polius, Matthew Ridsdill-Smith ★ The abundance of the short-lived radioisotopes 26-Al and 60-Fe in the early Solar system is usually explained by the Sun either forming from pre-enriched material, or the Sun's protosolar disc being polluted by a nearby supernova explosion from a massive star. Both hypotheses suffer from significant drawbacks: the former does not account for the dynamical evolution of star-forming regions, while in the latter the time for massive stars to explode as supernovae can be similar to, or even longer than, the lifetime of protoplanetary discs. In this paper, we extend the disc enrichment scenario to include the contribution of 26-Al from the winds of massive stars before they explode as supernovae. We use N-body simulations and a post-processing analysis to calculate the amount of enrichment in each disc, and we vary the stellar density of the star-forming regions. We find that stellar winds contribute to disc enrichment to such an extent that the Solar system's 26-Al/60-Fe ratio is reproduced in up to 50 per cent of discs in dense (rho = 1000Msun pc^{-3}) star-forming regions. When winds are a significant contributor to the SLR enrichment, we find that Solar system levels of enrichment can occur much earlier (before 2.5 Myr) than when enrichment occurs from supernovae, which start to explode at later ages ($>$4 Myr). We find that Solar system levels of enrichment all but disappear in low-density star-forming regions (rho $<$ 10Msun pc^{-3}), implying that the Solar system must have formed in a dense, populous star-forming region if 26-Al and 60-Fe were delivered directly to the protosolar disc from massive-star winds and supernovae.

42. Paradigmatic examples for testing models of optical light polarization by spheroidal dust

C. Peest, R. Siebenmorgen, F. Heymann, T. Vannieuwenhuyse, M. Baes ★ We present a general framework on how the polarization of radiation due to scattering, dichroic extinction, and birefringence of aligned spheroidal dust grains can be implemented and tested in 3D Monte Carlo radiative transfer (MCRT) codes. We derive a methodology for solving the radiative transfer equation governing the changes of the Stokes parameters in dust-enshrouded objects. We utilize the Müller matrix, and the extinction, scattering, linear, and circular polarization cross sections of spheroidal grains as well as electrons. An established MCRT code is used and its capabilities are extended to include the Stokes formalism. We compute changes in the polarization state of the light by scattering, dichroic extinction, and birefringence on spheroidal grains. The dependency of the optical depth and the albedo on the polarization is treated. The implementation of scattering by spheroidal grains both for random walk steps as well as for directed scattering (peel-off) are described. The observable polarization of radiation of the objects is determined through an angle binning method for photon packages leaving the model space as well as through an inverse ray-tracing routine for the generation of images. We present paradigmatic examples for which we derive analytical solutions of the optical light polarization by spheroidal dust particles. These tests are suited for benchmark verification of MCpol and other such codes, and allow to quantify the numerical precision reached. We demonstrate that MCpol is in excellent agreement to within 0.1% of the Stokes parameters when compared to the analytical solutions.

43. Correlating Changes in Spot Filling Factors with Stellar Rotation: The Case of LkCa 4

Facundo Pérez Paolino, Jeffrey S. Bary, Michael S. Petersen, Kimberly Ward-Duong, Benjamin M. Tofflemire, Katherine B. Follette, Heidi Mach ★ We present a multi-epoch spectroscopic study of LkCa 4, a heavily spotted non-accreting T Tauri star. Using SpeX at NASA's Infrared Telescope Facility (IRTF), 12 spectra were collected over five consecutive nights, spanning ≈ 1.5 stellar rotations. Using the IRTF SpeX Spectral Library, we constructed empirical composite models of spotted stars by combining a warmer (photosphere) standard star spectrum with a cooler (spot) standard weighted by the spot filling factor, f_{spot}. The best-fit models spanned two photospheric component temperatures, $T_{phot} = 4100$ K (K7V) and 4400 K (K5V), and one spot component temperature, $T_{spot} = 3060$ K (M5V) with an A_V of 0.3. We find values of f_{spot} to vary between 0.77 and 0.94 with an average uncertainty of $\sim$0.04. The variability of f_{spot} is periodic and correlates with its 3.374 day rotational period. Using a mean value for f_{spot}^{mean} to represent the total spot coverage, we calculated spot corrected values for T_{eff} and $L_\star$. Placing these values alongside evolutionary models developed for heavily spotted young stars, we infer mass and age ranges of 0.45-0.6 $M_\odot$ and 0.50-1.25 Myr, respectively. These inferred values represent a twofold increase in the mass and a twofold decrease in the age as compared to standard evolutionary models. Such a result highlights the need for constraining the contributions of cool and warm regions of young stellar atmospheres when estimating T_{eff} and $L_\star$ to infer masses and ages as well as the necessity for models to account for the effects of these regions on the early evolution of low-mass stars.

44. An SMA Survey of Chemistry in Disks around Herbig AeBe Stars

Jamila Pegues, Karin I. Öberg, Chunhua Qi, Sean M. Andrews, Jane Huang, Charles J. Law, Romane Le Gal, Luca Matrà, David J. Wilner ★ Protoplanetary disks around Herbig AeBe stars are exciting targets for studying the chemical environments where giant planets form. Save for a few disks, however, much of Herbig AeBe disk chemistry is an open frontier. We present a Submillimeter Array (SMA) $\sim$213-268 GHz pilot survey of mm continuum, CO isotopologues, and other small molecules in disks around five Herbig AeBe stars (HD 34282, HD 36112, HD 38120, HD 142666, and HD 144432). We detect or tentatively detect ^{12}CO 2–1 and ^{13}CO 2–1 from four disks; $C^{18}O$ 2–1 and HCO^+ 3–2 from three disks; HCN 3–2, CS 5–4, and DCO^+ 3–2 from two disks; and C_2H 3–2 and DCN 3–2 from one disk each. H_2CO 3–2 is undetected at the sensitivity of our observations. The mm continuum images of HD 34282 suggest a faint, unresolved source $\sim$5 arcsec away, which could arise from a distant orbital companion or an extended spiral arm. We fold our sample into a compilation of T Tauri and Herbig AeBe/F disks from the literature. Altogether, most line fluxes generally increase with mm continuum flux. Line flux ratios between CO 2–1 isotopologues are nearest to unity for the Herbig AeBe/F disks. This may indicate emitting layers with relatively similar, warmer temperatures and more abundant CO relative to disk dust mass. Lower HCO^+ 3–2 flux ratios may reflect less ionization in Herbig AeBe/F disks. Smaller detection rates and flux ratios for DCO^+ 3–2, DCN 3–2, and H_2CO 3–2 suggest smaller regimes of cold chemistry around the luminous Herbig AeBe/F stars.

45. Photometric and Spectroscopic monitoring of YSOs in nearby star forming regions. I. Eruptive YSOs

Carlos Contreras Peña, Gregory J. Herczeg, Mizna Ashraf, Jessy Jose, Ho-Gyu Lee, Doug Johnstone, Jeong-Eun Lee, Xing-yu Zhou, Hanpu Liu, Sung-Yong Yoon ★ Mid-infrared (mid-IR) variability in young stellar objects (YSOs) is driven by several physical mechanisms, which produce a variety of amplitudes and light curve shapes. One of these mechanisms, variable disk accretion is predicted by models of episodic accretion to drive secular variability, including in the mid-IR. Because the largest accretion bursts are rare, adding new objects to the YSO eruptive variable class aids our understanding of the episodic accretion phenomenon and its possible impact on stellar and planetary formation. A previous analysis of 6.5 yr of NeoWISE light curves (3-5 μm) of 7000 nearby YSOs found an increase in the fraction of variability and variability amplitude for objects at younger stages of evolution. To help interpret these light curves, we have obtained low- and high-resolution near-IR spectra of 78 objects from this sample of YSOs. In this work, we present the analysis of nine nearby YSOs (d<1 kpc) that show the characteristics of known classes of eruptive variable YSOs. We find one FUor-like source, one EX Lupi-type object, and six YSOs with mixed characteristics, or V1647 Ori-like objects. The varied characteristics observed in our sample are consistent with recent discoveries of eruptive YSOs. We discuss how a wide range in YSO outburst parameters (central mass, maximum accretion rate during outburst, evolutionary stage and/or instability leading to the outburst) may play a significant role in the observed spectro-photometric properties of YSO outbursts.

46. X3: a high-mass Young Stellar Object close to the supermassive black hole Sgr A*

Florian Peißker, Michal Zajacek, Nadeen B. Sabha, Masato Tsuboi, Jihane Moultaka, Lucas Labadie, Andreas Eckart, Vladimir Karas, Lukas Steiniger, Matthias Subroweit, Anjana Suresh, Maria Melamed, Yann Clenet ★ To date, the proposed observation of Young Stellar Objects (YSOs) in the Galactic center (GC) still raises the question where and how these objects could have formed due to the violent vicinity of Sgr A*. Here, we report the multi-wavelength detection of a highly dynamic YSO close to Sgr A* that might be a member of the IRS13 cluster. We observe the beforehand known coreless bow-shock source X3 in the near- and mid-infrared (NIR/MIR) with SINFONI (VLT), NACO (VLT), ISAAC (VLT), VISIR (VLT), SHARP (NTT), and NIRCAM2 (KECK). In the radio domain, we use CO continuum and H30α ALMA observations to identify system components at different temperatures and locations concerning the central stellar source. It is suggested that these radio/submm observations in combination with the NIR Brγ line can be associated with a protoplanetary disk of the YSO which is consistent with manifold VISIR observations that reveal complex molecules and elements such as PAH, SIV, NeII and ArIII in a dense and compact region. Based on the photometric multi-wavelength analysis, we infer the mass of $15^{+10}_{-5} M_{\odot}$ for the YSO with a related age of a few 10^4 yr. Due to this age estimate and the required relaxation time scales for high-mass stars, this finding is an indication for ongoing star formation in the inner parsec. The proper motion and 3d distance imply a relation of X3 and IRS13. We argue that IRS13 may serve as a birthplace for young stars that are ejected due to the evaporation of the cluster.

47. HOPS 361-C's Jet Decelerating and Precessing Through NGC 2071 IR

Adam E. Rubinstein, Nicole Karnath, Alice C. Quillen, Samuel Federman, Joel D. Green, Edward T. Chambers, Dan M. Watson, S. Thomas Megeath ★ We present a two-epoch Hubble Space Telescope (HST) near-infrared (NIR) study of NGC 2071 IR highlighting HOPS 361-C, a protostar producing an arced 0.2 parsec-scale jet. Proper motions for the brightest knots decrease from 350 to 100 km/s with increasing distance from the source. The [Fe II] and Paβ emission line intensity ratio gives a velocity jump through each knot of 40-50 km/s. We show a new [O I] 63 μm spectrum taken with the German REciever for Astronomy at Terahertz frequencies (GREAT) instrument aboard Stratospheric Observatory for Infrared Astronomy (SOFIA), which give a low jet inclination. Proper motions and jump velocities then estimate total flow speed throughout the jet. We model knot positions and speeds with a precessing jet that decelerates within the host molecular cloud. The measurements are matched with a precession period of a few thousand years and half opening angle of 15deg. The [Fe II] 1.26 μm to 1.64 μm line intensity ratio gives the extinction to each knot ranging from 5-30 mag. Relative to $\sim$14 mag of extinction through the cloud from $C^{18}O$ emission maps, the jet is well embedded at a fractional depth from 1/5 to 4/5, and can interact with the cloud. Our model suggests the jet is locally dissipated over 0.2 pc. This may be because knots sweep through a wide angle, giving the cloud time to fill in cavities opened by the jet. This contrasts with nearly unidirectional protostellar jets that puncture host clouds and can propagate significantly further than a quarter pc.

48. Probing the Global Dust Properties and Cluster Formation Potential of the Giant Molecular Cloud G148.24+00.41

Vineet Rawat, M. R. Samal, D. L. Walker, A. Zavagno, A. Tej, G. Marton, D. K. Ojha, Davide Elia, W. P. Chen, J. Jose, C Eswaraiah ★ Clouds more massive than about 10^5 $M_{\odot}$ are potential sites of massive cluster formation. Studying the properties of such clouds in the early stages of their evolution offers an opportunity to test various cluster formation processes. We make use of CO, Herschel, and UKIDSS observations to study one such cloud, G148.24+00.41. Our results show the cloud to be of high mass ($\sim 1.1 \times 10^5$ $M_{\odot}$), low dust temperature ($\sim$ 14.5 K), nearly circular (projected radius $\sim$ 26 pc), and gravitationally bound with a dense gas fraction of $\sim$ 18% and a density profile with a power-law index of ~ -1.5. Comparing its properties with those of nearby molecular clouds, we find that G148.24+00.41 is comparable to the Orion-A molecular cloud in terms of mass, size, and dense gas fraction. From our analyses, we find that the central area of the cloud is actively forming protostars and is moderately fractal with a Q-value of $\sim$ 0.66. We also find evidence of global mass-segregation in the cloud, with a degree of mass-segregation (Λ_{MSR}) $\approx$ 3.2. We discuss these results along with the structure and compactness of the cloud, the spatial and temporal distribution of embedded stellar population, and their correlation with the cold dust distribution, in the context of high-mass cluster formation. Comparing our results with models of star cluster formation, we conclude that the cloud has the potential to form a cluster in the mass range $\sim$ 2000–3000 $M_{\odot}$ through dynamical hierarchical collapse and assembly of both gas and stars.

49. Formation of supermassive stars in the first star clusters

Bastián Reinoso, Ralf S. Klessen, Dominik Schleicher, Simon C. O. Glover, P. Solar ★ The formation of supermassive stars is believed to be an essential intermediate step for the formation of the massive black hole seeds that become the supermassive black holes powering the quasars observed in the early Universe. Numerical simulations have shown that supermassive stars can form in atomic-cooling halos when protostars reach accretion rates higher than $\sim 10^{-2}$ $M_\odot$ yr^{-1} and fragmentation is suppressed on pc scales. It is however still uncertain if a supermassive star still emerges when fragmentation occurs at smaller scales and a cluster of stars is formed instead. In this work we explore the problem of massive object formation due to the interplay of collisions and accretion in star clusters at low metallicity. We model a small embedded cluster of accreting protostars following sub-parsec scale fragmentation during the collapse of a primordial gas cloud and follow its evolution by performing N-body plus hydrodynamical simulations. Our results show that supermassive stars with 10^3 and 10^4 $M_\odot$ are always formed due to the interplay of collisions and accretion, and in some cases these objects are part of a binary system. The resulting supermassive star is surrounded by tens of smaller stars with typical masses in the range 1-100 $M_\odot$.

50. Monitoring of the polarized H_2O maser emission around the massive protostars W75N(B)-VLA1 and W75N(B)-VLA2

G. Surcis, W. H. T. Vlemmings, C. Goddi, J. M. Torrelles, J. F. Gómez, A. Rodríguez-Kamenetzky, C. Carrasco-González, S. Curiel, S. -W. Kim, J. -S. Kim, H. J. van Langevelde ★ Several radio sources have been detected in the HMSFR W75N(B), among them the massive YSOs VLA1 and VLA2 are of great interest. These are thought to be in different evolutionary stages. In particular, VLA1 is at the early stage of the photoionization and it is driving a thermal radio jet, while VLA2 is a thermal, collimated ionized wind surrounded by a dusty disk or envelope. In both sources 22 GHz water masers have been detected in the past. Those around VLA1 show a persistent distribution along the radio jet and those around VLA2 have instead traced the evolution from a non-collimated to a collimated outflow over a period of 20 years. By monitoring the polarized emission of the water masers around both VLA1 and VLA2 over a period of 6 years, we aim to determine whether the maser distributions show any variation over time and whether the magnetic field behaves accordingly. The EVN was used in full polarization and phase-reference mode to measure the absolute positions of the masers and to determine both the orientation and the strength of the magnetic field. We observed four epochs separated by two years from 2014 to 2020. We detected polarized emission from the water masers around both the YSOs in all the epochs. We find that the masers around VLA1 are tracing a nondissociative shock originating from the expansion of the thermal radio jet, while the masers around VLA2 are tracing an asymmetric expansion of the gas that is halted in the northeast where the gas likely encounters a very dense medium. We also found that the magnetic field inferred from the water masers in each epoch can be considered as a portion of a quasi-static magnetic field estimated in that location rather than in that time. This allowed us to study locally the morphology of the magnetic field around both YSOs in a larger area by considering the vectors estimated in all the epochs as a whole.

51. Exciting spiral arms in protoplanetary discs from flybys

Jeremy L. Smallwood, Chao-Chin Yang, Zhaohuan Zhu, Rebecca G. Martin, Ruobing Dong, Nicolás Cuello, Andrea Isella ★ Spiral arms are observed in numerous protoplanetary discs. These spiral arms can be excited by companions, either on bound or unbound orbits. We simulate a scenario where an unbound perturber, i.e. a flyby, excites spiral arms during a periastron passage. We run three-dimensional hydrodynamical simulations of a parabolic flyby encountering a gaseous protoplanetary disc. The perturber mass ranges from $10\,\mathrm{M_J}$ to $1\,\mathrm{M_\odot}$. The perturber excites a two-armed spiral structure, with a more prominent spiral feature for higher mass perturbers. The two arms evolve over time, eventually winding up, consistent with previous works. We focus on analysing the pattern speed and pitch angle of these spirals during the whole process. The initial pattern speed of the two arms are close to the angular velocity of the perturber at periastron, and then it decreases over time. The pitch angle also decreases over time as the spiral winds up. The spirals disappear after several local orbital times. An inclined prograde orbit flyby induces similar disc substructures as a coplanar flyby. A solar-mass flyby event causes increased eccentricity growth in the protoplanetary disc, leading to an eccentric disc structure which dampens over time. The spirals' morphology and the disc eccentricity can be used to search for potential unbound stars or planets around discs where a flyby is suspected. Future disc observations at high resolution and dedicated surveys will help to constrain the frequency of such stellar encounters in nearby star-forming regions.

52. Quiescence of an Outburst of a Low-Mass Young Stellar Object: LDN1415-IRS

Koshvendra Singh, Devendra K. Ojha, Joe P. Ninan, Saurabh Sharma, Supriyo Ghosh, Arpan Ghosh, Bhuwan C. Bhatt, Devendra K. Sahu ★ LDN1415-IRS, a low-mass young stellar object (YSO) went into an outburst between 2001 and 2006, illuminating a surrounding nebula, LDN1415-Neb. LDN1415-Neb was found to have brightened by I=3.77 mag by April 2006. The optical light curve covering $\sim$ 15.5 years, starting from October 2006 to January 2022, is presented in this study. The initial optical spectrum indicated the presence of winds in the system but the subsequent spectra have no wind indicators. The declining light curve and the absence of the P-Cygni profile in later epoch spectra indicate that the star and nebula system is retrieving back from its outburst state. Two Herbig-Haro objects (HHOs) are positioned linearly with respect to the optical brightness peak of the nebula, probably indicating the circumstellar disk being viewed edge-on. Our recent deep near-infrared (NIR) imaging using TANSPEC has revealed the presence of a nearby star-like source, south of the LDN1415-IRS, at an angular distance of $\sim$ 5.4 arcsec.

53. 3D Radiative Transfer Modelling and Virial Analysis of Starless Cores in the B10 Region of the Taurus Molecular Cloud

Samantha Scibelli, Yancy Shirley, Anika Schmiedeke, Brian Svoboda, Ayushi Singh, James Lilly, Paola Caselli ★ Low-mass stars like our Sun begin their evolution within cold (10 K) and dense ($\sim 10^5$ cm^{-3}) cores of gas and dust. The physical structure of starless cores is best probed by thermal emission of dust grains. We present a high resolution dust continuum study of the starless cores in the B10 region of the Taurus Molecular Cloud. New observations at 1.2mm and 2.0mm (12" and 18" resolution) with the NIKA2 instrument on the IRAM 30m have probed the inner regions of 14 low-mass starless cores. We perform sophisticated 3D radiative transfer modelling for each of these cores through the radiative transfer framework *pandora*, which utilizes RADMC-3D. Model best-fits constrain each cores' central density, density slope, aspect ratio, opacity, and interstellar radiation field strength. These 'typical' cores in B10 span central densities from $5 \times 10^4 - 1 \times 10^6$ cm^{-3}, with a mean value of 2.6×10^5 cm^{-3}. We find the dust opacity laws assumed in the 3D modelling, as well as the estimates from *Herschel*, have dust emissivity indices, β's, on the lower end of the distribution constrained directly from the NIKA2 maps, which averages to $\beta = 2.01 \pm 0.48$. From our 3D density structures and archival NH_3 data, we perform a self-consistent virial analysis to assess each core's stability. Ignoring magnetic field contributions, we find 9 out of the 14 cores (64%) are either in virial equilibrium or are bound by gravity and external pressure. To push the bounded cores back to equilibrium, an effective magnetic field difference of only $\sim 15\mu$G is needed.

54. Stellar associations powering HII regions I. Defining an evolutionary sequence

Fabian Scheuermann et al. ★ Connecting the gas in HII regions to the underlying source of the ionizing radiation can help us constrain the physical processes of stellar feedback and how HII regions evolve over time. With PHANGS−MUSE we detect nearly 24,000 HII regions across 19 galaxies and measure the physical properties of the ionized gas (e.g. metallicity, ionization parameter, density). We use catalogues of multi-scale stellar associations from

PHANGS−HST to obtain constraints on the age of the ionizing sources. We construct a matched catalogue of 4,177 HII regions that are clearly linked to a single ionizing association. A weak anti-correlation is observed between the association ages and the Hα equivalent width EW(Hα), the Hα/FUV flux ratio and the ionization parameter, log q. As all three are expected to decrease as the stellar population ages, this could indicate that we observe an evolutionary sequence. This interpretation is further supported by correlations between all three properties. Interpreting these as evolutionary tracers, we find younger nebulae to be more attenuated by dust and closer to giant molecular clouds, in line with recent models of feedback-regulated star formation. We also observe strong correlations with the local metallicity variations and all three proposed age tracers, suggestive of star formation preferentially occurring in locations of locally enhanced metallicity. Overall, EW(Hα) and log q show the most consistent trends and appear to be most reliable tracers for the age of an HII region.

55. Disks around young planetary-mass objects: Ultradeep Spitzer imaging of NGC1333

Aleks Scholz, Koraljka Muzic, Ray Jayawardhana, Victor Almendros-Abad, Isaac Wilson ★ We report on a sensitive infrared search for disks around isolated young planetary-mass objects (PMOs) in the NGC1333 cluster, by stacking 70 Spitzer/IRAC frames at 3.6 and 4.5 μm. Our co-added images go >2.3 mag deeper than single-epoch frames, and cover 50 brown dwarfs, 15 of which have M9 or later spectral types. Spectral types >M9 correspond to masses in the giant planet domain, i.e., near or below the Deuterium-burning limit of 0.015 Msol. Five of the 12 PMOs show definitive evidence of excess, implying a disk fraction of 42%, albeit with a large statistical uncertainty given the small sample. Comparing with measurements for higher-mass objects, the disk fraction does not decline substantially with decreasing mass in the sub-stellar domain, consistent with previous findings. Thus, free-floating PMOs have the potential to form their own miniature planetary systems. We note that only one of the six lowest-mass objects in NGC1333, with spectral type L0 or later, has a confirmed disk. Reviewing the literature, we find that the lowest mass free-floating objects with firm disk detections have masses 0.01 Msol (or 10 MJup). It is not clear yet whether even lower mass objects harbor disks. If not, it may indicate that 10 MJup is the lower mass limit for objects that form like stars. Our disk detection experiment on deep Spitzer images paves the way for studies with JWST at longer wavelengths and higher sensitivity, which will further explore disk prevalence and formation of free-floating PMOs.

56. JCMT BISTRO Observations: Magnetic Field Morphology of Bubbles Associated with NGC 6334

Mehrnoosh Tahani et al. (BISTRO collaboration) ★ We study the HII regions associated with the NGC 6334 molecular cloud observed in the sub-millimeter and taken as part of the B-fields In STar-forming Region Observations (BISTRO) Survey. In particular, we investigate the polarization patterns and magnetic field morphologies associated with these HII regions. Through polarization pattern and pressure calculation analyses, several of these bubbles indicate that the gas and magnetic field lines have been pushed away from the bubble, toward an almost tangential (to the bubble) magnetic field morphology. In the densest part of NGC 6334, where the magnetic field morphology is similar to an hourglass, the polarization observations do not exhibit observable impact from HII regions. We detect two nested radial polarization patterns in a bubble to the south of NGC 6334 that correspond to the previously observed bipolar structure in this bubble. Finally, using the results of this study, we present steps (incorporating computer vision; circular Hough Transform) that can be used in future studies to identify bubbles that have physically impacted magnetic field lines.

57. Can we observe the ion-neutral drift velocity in prestellar cores?

Aris Tritsis, Shantanu Basu, Christoph Federrath ★ Given the low ionization fraction of molecular clouds, ambipolar diffusion is thought to be an integral process in star formation. However, chemical and radiative-transfer effects, observational challenges, and the fact that the ion-neutral drift velocity is inherently very small render a definite detection of ambipolar diffusion extremely non-trivial. Here, we study the ion-neutral drift velocity in a suite of chemodynamical, non-ideal magnetohydrodynamic (MHD), two-dimensional axisymmetric simulations of prestellar cores where we alter the temperature, cosmic-ray ionization rate, visual extinction, mass-to-flux ratio, and chemical evolution. Subsequently, we perform a number of non-local thermodynamic equilibrium (non-LTE) radiative-transfer calculations considering various idealized and non-idealized scenarios in order to assess which factor (chemistry, radiative transfer and/or observational difficulties) is the most challenging to overcome in our efforts to detect the ion-neutral drift velocity. We find that temperature has a significant effect in the amplitude of the drift velocity with the coldest modelled cores (T = 6 K) exhibiting drift velocities comparable to the sound speed. Against expectations, we find that in idealized scenarios (where two species are perfectly chemically co-evolving) the drift velocity "survives" radiative-transfer effects and can in principle be observed. However, we find that observational challenges and chemical effects can significantly hinder our view of the ion-neutral drift velocity. Finally, we propose that HCN and $HCNH^+$, being chemically co-evolving, could be used in future observational studies aiming to measure the ion-neutral drift velocity.

58. Star-Crossed Lovers DI Tau A and B: Orbit Characterization and Physical Properties Determination

Shih-Yun Tang, Asa G. Stahl, L. Prato, G. H. Schaefer, Christopher M. Johns-Krull, Brian A. Skiff, Charles A. Beichman, Taichi Uyama ★ The stellar companion to the weak-line T Tauri star DI Tau A was first discovered by the lunar occultation technique in 1989 and was subsequently confirmed by a speckle imaging observation in 1991. It has not been detected since, despite being targeted by five different studies that used a variety of methods and spanned more than 20 years. Here, we report the serendipitous rediscovery of DI Tau B during our Young Exoplanets Spectroscopic Survey (YESS). Using radial velocity data from YESS spanning 17 years, new adaptive optics observations from Keck II, and a variety of other data from the literature, we derive a preliminary orbital solution for the system that effectively explains the detection and (almost all of the) non-detection history of DI Tau B. We estimate the dynamical masses of both components, finding that the large mass difference (q $\sim$0.17) and long orbital period ($\gtrsim$35 years) make DI Tau system a noteworthy and valuable addition to studies of stellar evolution and pre-main-sequence models. With a long orbital period and a small flux ratio (f2/f1) between DI Tau A and B, additional measurements are needed for a better comparison between these observational results and pre-main-sequence models. Finally, we report an average surface magnetic field strength ($\bar{B}$) for DI Tau A, of $\sim$0.55 kG, which is unusually low in the context of young active stars.

59. Magnetohydrodynamic Model of Late Accretion onto a Protoplanetary Disk: Cloudlet Encounter Event

Masaki Unno, Tomoyuki Hanawa, Shinsuke Takasao ★ Recent observations suggest late accretion, which is generally nonaxisymmetric, onto protoplanetary disks. We investigated nonaxisymmetric late accretion considering the effects of magnetic fields. Our model assumes a cloudlet encounter event at a few hundred au scale, where a magnetized gas clump (cloudlet) encounters a protoplanetary disk. We studied how the cloudlet size and the magnetic field strength affect the rotational velocity profile in the disk after the cloudlet encounter. The results show that a magnetic field can either decelerate or accelerate the rotational motion of the cloudlet material, primarily depending on the relative size of the cloudlet to the disk thickness. When the cloudlet size is comparable to or smaller than the disk thickness, magnetic fields only decelerate the rotation of the colliding cloudlet material. However, if the cloudlet size is larger than the disk thickness, the colliding cloudlet material can be super-Keplerian as a result of magnetic acceleration. We found that the vertical velocity shear of the cloudlet produces a magnetic tension force that increases the rotational velocity. The acceleration mechanism operates when the initial plasma β is $\beta \lesssim 2 \times 10^1$. Our study shows that magnetic fields modify the properties of spirals formed by tidal effects. These findings may be important for interpreting observations of late accretion.

60. Terrestrial planet formation from a ring

J. M. Y. Woo, A. Morbidelli, S. L. Grimm, J. Stadel, R. Brasser ★ It has been long proposed that, if all the terrestrial planets form within a tiny ring of solid material at around 1 AU, the concentrated mass-distance distribution of the current system can be reproduced. Recent planetesimal formation models also support this idea. In this study, we revisit the ring model by performing a number of high-resolution N-body simulations for 10 Myr of a ring of self-interacting planetesimals, with various radial distributions of the gas disc. We found that even if all the planetesimals form at 1 AU in a minimum mass solar nebula-like disc, the system tends to spread radially as accretion proceeds, resulting in a system of planetary embryos lacking mass-concentration at 1 AU. Modifying the surface density of the gas disc into a concave shape with a peak at 1 AU helps to maintain mass concentrated at 1 AU and solve the radial dispersion problem. We further propose that such a disc should be short lived (<= 1 Myr) and with a shallower radial gradient in the innermost region (< 1 AU) than previously proposed to prevent a too-rapid growth of Earth. Future studies should extend to 100 Myr the most promising simulations and address in a self-consistent manner the evolution of the asteroid belt and its role in the formation of the terrestrial planets.

61. Massive Protostellar Disks as a Hot Laboratory of Silicate Grain Evolution

Ryota Yamamuro, Kei E. I. Tanaka, Satoshi Okuzumi ★ Typical accretion disks around massive protostars are hot enough for water ice to sublimate. We here propose to utilize the massive protostellar disks for investigating the collisional evolution of silicate grains with no ice mantle, which is an essential process for the formation of rocky planetesimals in protoplanetary disks around lower-mass stars. We for the first time develop a model of massive protostellar disks that includes the coagulation, fragmentation, and radial drift of dust. We show that the maximum grain size in the disks is limited by collisional fragmentation rather than by radial drift. We derive analytic formulas that produce the radial distribution of the maximum grain size and dust surface density in the steady state. Applying the analytic formulas to the massive protostellar disk of GGD27-MM1, where the grain size is constrained from a millimeter polarimetric observation, we infer that the silicate grains in this disk fragment at collision velocities above 10 m/s. The inferred fragmentation threshold velocity is lower than the maximum grain collision velocity in typical protoplanetary disks around low-mass stars, implying that coagulation alone may not lead to the formation of rocky planetesimals in those disks. With future measurements of grain sizes in massive protostellar disks, our model will provide more robust constraints on the sticking property of silicate grains.

62. Multiple Rings and Asymmetric Structures in the Disk of SR 21

Yi Yang, Hauyu Baobab Liu, Takayuki Muto, Jun Hashimoto, Ruobing Dong, Kazuhiro Kanagawa, Munetake Momose, Eiji Akiyama, Yasuhiro Hasegawa, Takashi Tsukagoshi, Mihoko Konishi, Motohide Tamura ★ Crescent-like asymmetric dust structures discovered in protoplanetary disks indicate dust aggregations. Thus, the research on them helps us understand the planet formation process. Here we analyze the ALMA data of the protoplanetary disk around the T-Tauri star SR 21, which has asymmetric structures detected in previous sub-millimeter observations. Imaged at ALMA Band 6 (1.3 mm) with a spatial resolution of about 0.04 arcsec, the disk is found to consist of two rings and three asymmetric structures, with two of the asymmetric structures being in the same ring. Compared to the Band 6 image, the Band 3 (2.7 mm) image also shows the three asymmetric structures but with some clumps. The elongated asymmetric structures in the outer ring could be due to the interactions of a growing planet. By fitting the Band 3 and Band 6 dust continuum data, two branches of solutions of maximum dust size in the disk are suggested: one is larger than 1 mm, and the other is smaller than 300 μm. High-resolution continuum observations at longer wavelengths as well as polarization observations can help break the degeneracy. We also suggest that the prominent spiral previously identified in VLT/SPHERE observations to the south of the star at 0.25 arcsec may be the scattered light counterpart of the Inner Arc, and the structure is a dust-trapping vortex in nature. The discovered features in SR 21 make it a good target for studying the evolution of asymmetric structures and planet formation.

63. Spatially Resolving PAHs in Herbig Ae Disks with VISIR-NEAR at the VLT

Gideon Yoffe, Roy van Boekel, Aigen Li, L. B. F. M Waters, Koen Maaskant, Ralf Siebenmorgen, Mario van den Ancker, D. J. M Petit dit de la Roche, Bruno Lopez, Alexis Matter, Jozsef Varga, M. R Hogerheijde, Gerd Weigelt, R. D Oudmaijer, Eric Pantin, M. R Meyer, Jean-Charles Augereau, Thomas Henning ★ We use the long-slit spectroscopy mode of the VISIR-NEAR experiment to perform diffraction-limited observations of eight nearby Herbig Ae protoplanetary disks. We extract spectra for various locations along the slit with a spectral resolution of R = 300 and perform a compositional fit at each spatial location using spectral templates of silicates and the four PAH bands. This yields the intensity vs. location profiles of each species. Results. We could obtain spatially-resolved intensity profiles of the PAH emission features in the N-band for five objects (AB Aurigae, HD 97048, HD 100546, HD 163296, and HD 169142). We observe two kinds of PAH emission geometry in our sample: centrally-peaked (HD 97048) and ring-like (AB Aurigae, HD 100546, HD 163296, and potentially HD 169142). Comparing the spatial PAH emission profiles with near-infrared scattered light images, we find a strong correlation in the disk sub-structure but a difference in radial intensity decay rate. The PAH emission shows a less steep decline with distance from the star. Finally, we find a correlation between the presence of (sub-) micron-sized silicate grains leading to the depletion of PAH emission within the inner regions of the disks. In this work, we find the following: (1) PAH emission traces the extent of Herbig Ae disks to a considerable radial distance. (2) The correlation between silicate emission within the inner regions of disks and the depletion of PAH emission can result from dust-mixing and PAH coagulation mechanisms and competition over UV photons. (3) For all objects in our sample, PAHs undergo stochastic heating across the entire spatial extent of the disk and are not saturated. (4) The difference in radial intensity decay rates between the PAHs and scattered-light profiles may be attributed to shadowing and dust-settling effects, which affect the scattering grains more than the PAHs.

64. Distances to nearby molecular clouds traced by young stars

Miaomiao Zhang ★ I present a catalog of distances to 63 molecular clouds located within 2.5 kpc of the Sun. The cloud distances are derived based on utilizing the Gaia DR3 parallaxes of the young stellar objects (YSOs). By identifying AllWISE YSO candidates (YSOCs) with infrared excesses and combining them with published YSOC catalogs, I compile an all-sky YSOC sample that is devoid of a significant proportion of contaminants. Using Gaia DR3 astrometric measurements, I associate over 3000 YSOCs with 63 local clouds and obtain the average distance to each cloud by fitting the YSOC parallax distribution within the cloud. I find good agreements with typical scatter of $<10\%$ between my new cloud distances and previous distance estimates. Unlike cloud distances obtained using stellar extinction, my catalog provides distances to the relatively dense areas of local clouds, which makes them more appropriate references for investigating the physical properties of nearby dense regions.

65. Disk Evolution Study Through Imaging of Nearby Young Stars (DESTINYS): Diverse outcomes of binary-disk interactions

Yapeng Zhang, Christian Ginski, Jane Huang, Alice Zurlo, Hervé Beust, Jaehan Bae, Myriam Benisty, Antonio Garufi, Michiel R. Hogerheijde, Rob G. van Holstein, Matthew Kenworthy, Maud Langlois, Carlo F. Manara, Paola Pinilla, Christian Rab, Álvaro Ribas, Giovanni P. Rosotti, Jonathan Williams ★ Circumstellar disks do not evolve in isolation, as about half of solar-type stars were born in binary or multiple systems. Resolving disks in binary systems provides the opportunity to examine the influence of stellar companions on the outcomes of planet formation. We aim to investigate and compare disks in stellar multiple systems with near-infrared scattered-light imaging as part of the Disk Evolution Study Through Imaging of Nearby Young Stars (DESTINYS) program. We used polarimetric differential imaging with SPHERE/IRDIS at the VLT to search for scattered light from the circumstellar disks in three multiple systems, CHX 22, S CrA, and HP Cha. We performed astrometric and orbit analyses for the stellar companions using archival HST, VLT/NACO, and SPHERE data. Combined with the age and orbital constraints, the observed disk structures provide insights into the evolutionary history and the impact of the stellar companions. The small grains in CHX 22 form a tail-like structure surrounding the close binary, which likely results from a close encounter and capture of a cloudlet. S CrA shows intricate structures (tentative ringed and spiral features) in the circumprimary disk as a possible consequence of perturbations by companions. The circumsecondary disk is truncated and connected to the primary disk via a streamer, suggesting tidal interactions. In HP Cha, the primary disk is less disturbed and features a tenuous streamer, through which the material flows towards the companions. The comparison of the three systems spans a wide range of binary separation (50 - 500 au) and illustrates the decreasing influence on disk structures with the distance of companions. This agrees with the statistical analysis of exoplanet population in binaries, that planet formation is likely obstructed around close binary systems, while it is not suppressed in wide binaries.

See you in Kyoto for PP7!