The Star Formation Newsletter

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Links to sections

Cover image caption

The iconic gas and dust pillars of M16, or the Pillars of creation, as seen in a recent JWST NIRCAM image. M16 is at about 2 kpc from Earth. The intricated gas distribution carved by the feedback of the massive stars in M16 is mesmerizing. Along the edges of the pillars, particularly towards the top of the pillars, are red HH objects from stars still forming. These young stars are estimated to be only a few hundred thousand years old.

Credit: NASA, ESA, CSA, STScI

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. On the typical width of Herschel filaments

Ph. André, P. Palmeirim, D. Arzoumanian ★ Herschel studies suggest that nearby (d $<$ 500 pc) molecular filaments have a typical half-power width 0.1pc, but this finding has been questioned on the ground that the measured widths tend to increase with distance. Here we revisit the dependence of measured filament widths on distance or equivalently spatial resolution, in an effort to determine whether nearby molecular filaments have a characteristic half-power width or whether this is an artifact of the finite resolution of the Herschel data. We perform a convergence test on the B211/213 filament in Taurus, by degrading the resolution of the Herschel data several times and re-estimating the filament width from the resulting column density profiles. We also compare the widths measured for the Taurus filament and other filaments from the Herschel Gould Belt survey to those found for synthetic filaments with various types of simple, idealized column density profiles. We find that the measured filament widths do increase slightly as the spatial resolution worsens and/or the distance to the filaments increases. However, this trend is entirely consistent with what is expected from simple beam convolution for filaments with density profiles that are Plummer-like and have intrinsic half-power diameters 0.08-0.1 pc and logarithmic slopes 1.5 $<$ p $<$ 2.5 at large radii, as observed in many cases including the Taurus filament. Due to the presence of background noise fluctuations, deconvolution of the measured widths from the telescope beam quickly becomes inaccurate. We conclude that the typical half-power filament width 0.1 pc measured with Herschel in nearby clouds most likely reflects the presence of a true common scale in the filamentary structure of the cold interstellar medium, at least in the solar neighborhood. We suggest that this common scale may correspond to the magnetized turbulent correlation length in molecular clouds.

2. Sustained FU Orionis-type outbursts from colliding discs in stellar flybys

Elisabeth M. A. Borchert, Daniel J. Price, Christophe Pinte, Nicolás Cuello ★ We perform 3D hydrodynamics simulations of disc-disc stellar flybys with on-the-fly Monte Carlo radiative transfer. We show that pre-existing circumstellar discs around both stars result in fast rising ($\sim$yrs) outbursts lasting 2-5 times longer than for a star-disc flyby. The perturber always goes into outburst ($\dot{M} > 10^{-5}$ M$_\odot$ yr^{-1}). Whereas we find that the primary goes into a decades long outburst only when the flyby is retrograde to the circumprimary disc rotation. High accretion rates during the outburst are triggered by angular momentum cancellation in misaligned material generated by the encounter. A large fraction of accreted material is alien.

3. Gap-opening Planets Make Dust Rings Wider

Jiaqing Bi, Min-Kai Lin, Ruobing Dong ★ As one of the most commonly observed disk substructures, dust rings from high-resolution disk surveys appear to have different radial widths. Recent observations on PDS 70 and AB Aur reveal not only planets in the disk, but also the accompanying wide dust rings. We use three-dimensional dust-and-gas disk simulations to study whether gap-opening planets are responsible for the large ring width in disk observations. We find that gap-opening planets can widen rings of dust trapped at the pressure bump via planetary perturbations, even with the mid-plane dust-to-gas ratio approaching order unity and with the dust back-reaction accounted for. We show that the planet-related widening effect of dust rings can be quantified using diffusion-advection theory, and provide a generalized criterion for an equilibrated dust ring width in three-dimensional disk models. We also suggest that the ring width can be estimated using the gas turbulent viscosity $\alpha_{\rm turb}$, but with cautions about the Schmidt number greater than order unity.

4. Ices toward Massive YSOs: I. OCS, CO, OCN-, and CH3OH

A. C. A. Boogert, K. Brewer, A. Brittain, K. S Emerson ★ An important tracer of the origin and evolution of cometary ices is the comparison with ices found in dense clouds and towards Young Stellar Objects (YSOs). We present a survey of ices in the 2-5 micron spectra of 23 massive YSOs, taken with the NASA InfraRed Telescope Facility SpeX spectrometer. The 4.90 micron absorption band of OCS ice is detected in 20 sight-lines, more than five times the previously known detections. The absorption profile shows little variation and is consistent with OCS being embedded in CH3OH-rich ices, or proton-irradiated H2S or SO2-containing ices. The OCS column densities correlate well with those of CH3OH and OCN-, but not with H2O and apolar CO ice. This association of OCS with CH3OH and OCN- firmly establishes their formation location deep inside dense clouds or protostellar envelopes. The median composition of this ice phase towards massive YSOs, as a percentage of H2O, is CO:CH3OH:OCN-:OCS=24:20:1.53:0.15. CS, due to its low abundance, is likely not the main precursor to OCS. Sulfurization of CO is likely needed, although the source of this sulfur is not well constrained. Compared to massive YSOs, low mass YSOs and dense clouds have similar CO and CH3OH ice abundances, but less OCN- and more apolar CO, while OCS awaits detection. Comets tend to be under-abundant in carbon-bearing species, but this does not appear to be the case for OCS, perhaps signalling OCS production in protoplanetary disks.

5. Structured Distributions of Gas and Solids in Protoplanetary Disks

Jaehan Bae, Andrea Isella, Zhaohuan Zhu, Rebecca Martin, Satoshi Okuzumi, Scott Suriano ★ Recent spatially-resolved observations of protoplanetary disks revealed a plethora of substructures, including concentric rings and gaps, inner cavities, misalignments, spiral arms, and azimuthal asymmetries. This is the major breakthrough in studies of protoplanetary disks since Protostars and Planets VI and is reshaping the field of planet formation. However, while the capability of imaging substructures in protoplanetary disks has been steadily improving, the origin of many substructures are still largely debated. The structured distributions of gas and solids in protoplanetary disks likely reflect the outcome of physical processes at work, including the formation of planets. Yet, the diverse properties among the observed protoplanetary disk population, for example, the number and radial location of rings and gaps in the dust distribution, suggest that the controlling process may differ between disks and/or the outcome may be sensitive to stellar or disk properties. In this review, we (1) summarize the existing observations of protoplanetary disk substructures collected from the literature; (2) provide a comprehensive theoretical review of various processes proposed to explain observed protoplanetary disk substructures; (3) compare current theoretical predictions with existing observations and highlight future research directions to distinguish between different origins; and (4) discuss implications of state-of-the-art protoplanetary disk observations to protoplanetary disk and planet formation theory.

6. The Disk Population in a Distant Massive Protocluster

Yu Cheng, Jonathan C. Tan, John J. Tobin, Ruben Fedriani, Morten Andersen, Junfeng Wang ★ The unprecedented angular resolution and sensitivity of ALMA makes it possible to unveil disk populations in distant (>2 kpc), embedded young cluster environments. We have conducted an observation towards the central region of the massive protocluster G286.21+0.16 at 1.3 mm. With a spatial resolution of 23 mas and a sensitivity of 15 μJy beam^{-1}, we detect a total of 38 protostellar disks. These disks have dust masses ranging from about 53 to 1825 $M_\oplus$, assuming a dust temperature of 20 K. This sample is not closely associated with previously identified dense cores, as would be expected for disks around Class 0 protostars. Thus, we expect our sample, being flux limited, to be mainly composed of Class I/flat-spectrum source disks, since these are typically more massive than Class II disks. Furthermore, we find that the distributions of disk masses and radii are statistically indistinguishable with those of the Class I/flat-spectrum objects in the Orion molecular cloud, indicating similar processes are operating in G286.21+0.16 to regulate disk formation and evolution. The cluster center appears to host a massive protostellar system composed of three sources within 1200 au, including a potential binary with 600 au projected separation. Relative to this center, there is no evidence for widespread mass segregation in the disk population. We do find a tentative trend of increasing disk radius versus distance from the cluster center, which may point to the influence of dynamical interactions being stronger in the central regions.

7. The three-dimensional structure of Galactic molecular cloud complexes out to 2.5 kpc

T. E. Dharmawardena, C. A. L. Bailer-Jones, M. Fouesneau, D. Foreman-Mackey, P. Coronica, T. Colnaghi, T. Müller, J. Henshaw ★ Knowledge of the three-dimensional structure of Galactic molecular clouds is important for understanding how clouds are affected by processes such as turbulence and magnetic fields and how this structure effects star formation within them. Great progress has been made in this field with the arrival of the Gaia mission, which provides accurate distances to $\sim 10^9$ stars. Combining these distances with extinctions inferred from optical-IR, we recover the three-dimensional structure of 16 Galactic molecular cloud complexes at $\sim$ 1pc resolution using our novel three-dimensional dust mapping algorithm `Dustribution`. Using `astrodendro` we derive a catalogue of physical parameters for each complex. We recover structures with aspect ratios between 1 and 11, i.e. everything from near-spherical to very elongated shapes. We find a large variation in cloud environments that is not apparent when studying them in two-dimensions. For example, the nearby California and Orion A clouds look similar on-sky, but we find California to be more sheet-like, and massive, which could explain their different star-formation rates. In Carina, our most distant complex, we observe evidence for dust sputtering, which explains its measured low dust mass. By calculating the total mass of these individual clouds, we demonstrate that it is necessary to define cloud boundaries in three-dimensions in order to obtain an accurate mass; simply integrating the extinction overestimates masses. We find that Larson's relationship on mass vs radius holds true whether you assume a spherical shape for the cloud or take their true extents.

8. Razor-thin dust layers in protoplanetary disks: Limits on the vertical shear instability

C. P. Dullemond, A. Ziampras, D. Ostertag, C. Dominik ★ Context: Recent observations with the Atacama Large Millimeter Array (ALMA) have shown that the large dust aggregates observed at millimeter wavelengths settle to the midplane into a remarkably thin layer. Aims: We intend to find out if the geometric thinness of these layers is evidence against the vertical shear instability (VSI) operating in these disks. Methods: We performed hydrodynamic simulations of a protoplanetary disk with a locally isothermal equation of state, and let the VSI fully develop. We sprinkled dust particles and followed their motion as they got stirred up by the VSI. We determined for which grain size the layer becomes geometrically thin enough to be consistent with ALMA observations. We then verified if, with these grain sizes, it is still possible to generate a moderately optically thick layer at millimeter wavelengths, as observations appear to indicate. Results: We found that even very large dust aggregates with Stokes numbers close to unity get stirred up to relatively large heights above the midplane by the VSI, which is in conflict with the observed geometric thinness. For grains so large that the Stokes number exceeds unity, the layer can be made to remain thin, but we show that it is hard to make dust layers optically thick at ALMA wavelengths (e.g., tau(1.3mm)$>=$1) with such large dust aggregates. Conclusions: We conclude that protoplanetary disks with geometrically thin midplane dust layers cannot be VSI unstable, at least not down to the disk midplane. Explanations for the inhibition of the VSI include a reduced dust-to-gas ratio of the small dust grains that are responsible for the radiative cooling of the disk. A reduction of small grains by a factor of between 10 and 100 is sufficient to quench the VSI. Such a reduction is plausible in dust growth models, and still consistent with observations at optical and infrared wavelengths.

9. Episodic accretion and mergers during growth of massive protostars

Vardan G. Elbakyan, Sergei Nayakshin, Dominique M. -A. Meyer, Eduard I. Vorobyov ★ 3D simulations of high mass young stellar object (HMYSO) growth show that their circumstellar discs fragment onto multiple self-gravitating objects. Accretion of these by HMYSO may explain episodic accretion bursts discovered recently. We post-process results of a previous 3D simulation of a HMYSO disc with a 1D code that resolves the disc and object dynamics down to the stellar surface. We find that burst-like deposition of material into the inner disc seen in 3D simulations by itself does not always signify powerful accretion bursts. Only high density post-collapse clumps crossing the inner computational boundary may result in observable bursts. The rich physics of the inner disc has a significant impact on the expected accretion bursts: (1) In the standard turbulent viscosity discs, migrating objects can stall at a migration trap at the distance of a few au from the star. However, in discs powered by magnetised winds, the objects are able to cross the trap and produce bursts akin to those observed so far. (2) Migrating objects may interact with and modify the thermal (hydrogen ionisation) instability of the inner disc, which can be responsible for longer duration and lower luminosity bursts in HMYSOs. (3) If the central star is bloated to a fraction of an au by a previous episode of high accretion rate, or if the migrating object is particularly dense, a merger rather than a disc-mediated accretion burst results; (4) Object disruption bursts may be super-Eddington, leading to episodic feedback on HMYSO surroundings via powerful outflows.

10. The SOFIA Massive (SOMA) Star Formation Survey. IV. Isolated Protostars

Ruben Fedriani, Jonathan C. Tan, Zoie Telkamp, Yichen Zhang, Yao-Lun Yang, Mengyao Liu, Chi-Yan Law, Maria T. Beltran, Viviana Rosero, Kei E. I. Tanaka, Giuliana Cosentino, Prasanta Gorai, Juan Farias, Jan E. Staff, James M. De Buizer, Barbara Whitney ★ We present $\sim 10-40\,\mu$m *SOFIA*-FORCAST images of 11 "isolated" protostars as part of the *SOFIA* Massive (SOMA) Star Formation Survey, with this morphological classification based on $37\,\mu$m imaging. We develop an automated method to define source aperture size based on the gradient of its background-subtracted enclosed flux and apply this to build spectral energy distributions (SEDs). We fit the SEDs with radiative transfer models, based on the Turbulent Core Accretion (TCA) theory, to estimate key protostellar properties. Here we release the *sedcreator* python package that carries out these methods. The SEDs are generally well-fit by the TCA models, from which we infer initial core masses M_c ranging from $50 - 430\,M_\odot$, clump mass surface densities $\Sigma_{\rm cl} \sim 0.1 - 2.3\,{\rm g\,cm^{-2}}$ and current protostellar masses $m_* \sim 2 - 50\,M_\odot$. From a uniform analysis of the 40 sources in the full SOMA survey to date, we find that massive protostars form across a wide range of clump mass surface density environments, placing constraints on theories that predict a minimum threshold $\Sigma_{\rm cl}$ for massive star formation. However, the upper end of the $m_* - \Sigma_{\rm cl}$ distribution follows trends predicted by models of internal protostellar feedback that find greater star formation efficiency in higher $\Sigma_{\rm cl}$ conditions. We also investigate protostellar FIR variability by comparison with IRAS data, finding no significant variation over a ~40-year baseline.

11. Millimeter Dust Emission and Planetary Dynamics in the HD 106906 System

Anna Fehr, A. Meredith Hughes, Rebekah I. Dawson, Rachel E. Marino, Matan Ackelsberg, Jamar Kittling, Kevin M. Flaherty, Erika Nesvold, John Carpenter, Sean M. Andrews, Brenda Matthews, Katie Crotts, Paul Kalas ★ Debris disks are dusty, optically thin structures around main sequence stars. HD 106906AB is a short-period stellar binary, host to a wide separation planet, HD 106906b, and a debris disk. Only a few known systems include a debris disk and a directly imaged planet, and HD 106906 is the only one in which the planet is exterior to the disk. The debris disk is edge-on and highly asymmetric in scattered light. Here we resolve the disk structure at a resolution of 0.38" (39 au) with the Atacama Large Millimeter/submillimeter Array (ALMA) at a wavelength of 1.3 mm. We model the disk with both a narrow and broad ring of material, and find that a radially broad, axisymmetric disk between radii of ~50−100 au is able to capture the structure of the observations without evidence of any asymmetry or eccentricity, other than a tentative stellocentric offset. We place stringent upper limits on both the gas and dust content of a putative circumplanetary disk. We interpret the ALMA data in concert with scattered light observations of the inner ring and astrometric constraints on the planet's orbit, and find that the observations are consistent with a large-separation, low-eccentricity orbit for the planet. A dynamical analysis indicates that the central binary can efficiently stabilize planetesimal orbits interior to ~100 au, which relaxes the constraints on eccentricity and semimajor axis somewhat. The observational constraints are consistent with in situ formation via gravitational instability, but cannot rule out a scattering event as the origin for HD 106906b's current orbit.

12. 300: An ACA 870 μm Continuum Survey of Orion Protostars and their Evolution

Samuel Federman, S. Thomas Megeath, John J. Tobin, Patrick D. Sheehan, Riwaj Pokhrel, Nolan Habel, Amelia M. Stutz, William J. Fischer, Lee Hartmann, Thomas Stanke, Mayank Narang, Mayra Osorio, Prabhani Atnagulov, Rohan Rahatgaonkar ★ We present an 870 μm continuum survey of 300 protostars from the Herschel Orion Protostar Survey (HOPS) using the Atacama Compact Array (ACA). These data measure protostellar flux densities on envelope scales $\leq$ 8000 AU (20") and resolve the structure of envelopes with 1600 AU (4") resolution, a factor of 3-5 improvement in angular resolution over existing single dish 870 μm observations. We compare the ACA observations to Atacama Large Millimeter Array (ALMA) 12m array observations at 870 μm with ~0.1" (40 AU) resolution. Using the 12 meter data to measure the fluxes from disks and the ACA fluxes within 2500 au to measure the combined disk plus envelope fluxes, we calculate the 12 m/ACA 870 μm flux ratios. Our sample shows a clear evolution in this ratio. Class 0 protostars are mostly envelope-dominated with ratios < 0.5. In contrast, Flat Spectrum protostars are primarily disk-dominated with ratios near one, although with a number of face-on protostars with large envelopes. Class I protostars span the range from envelope to disk dominated. The increase in ratio is accompanied by a decrease in the envelope fluxes and estimated mass infall rates. We estimate that 80% of the mass is accreted during the envelope-dominated phase. We find that the 12m/ACA flux ratio is an evolutionary indicator that largely avoids the inclination and foreground extinction dependence of SED-based indicators.

13. Diffuse γ-ray emission around the massive star forming region of Carina Nebula Complex

Ting-Ting Ge, Xiao-Na Sun, Rui-Zhi Yang, Yun-Feng Liang, En-Wei Liang ★ We report the Fermi Large Area Telescope (Fermi-LAT) detection of the γ-ray emission toward the massive star forming region of Carina Nebula Complex (CNC). Using the latest source catalog and diffuse background models, we found that the GeV γ-ray emission in this region can be resolved into three different components. The GeV γ-ray emission from the central point source is considered to originate from the Eta Carina (η Car). We further found the diffuse GeV γ-ray emission around the CNC which can be modelled by two Gaussian disks with radii of 0.4 deg (region A) and 0.75 deg (region B), respectively. The GeV γ-ray emission from both the regions A and B have good spatial consistency with the derived molecular gas in projection on the sky. The GeV γ-ray emission of region A reveals a characteristic spectral shape of the pion-decay process, which indicates that the γ-rays are produced by the interactions of hadronic cosmic rays with ambient gas. The γ-rays spectrum of region B has a hard photon index of 2.12 $\pm$ 0.02, which is similar to other young massive star clusters. We argue that the diffuse GeV γ-ray emission in region A and region B likely originate from the interaction of accelerated protons in clusters with the ambient gas.

14. Internal or external magma oceans in the earliest protoplanets – perspectives from nitrogen and carbon fractionation

Damanveer S. Grewal, Johnny D. Seales, Rajdeep Dasgupta ★ When the extent of protoplanetary melting approached magma ocean (MO)-like conditions, alloy melts efficiently segregated from the silicates to form metallic cores. The nature of the MO of a differentiating protoplanet, i.e., internal or external MO (IMO or EMO), not only determines the abundances of life-essential volatiles like nitrogen (N) and carbon (C) in its core and mantle reservoirs but also the timing and mechanism of volatile loss. Whether the earliest formed protoplanets had IMOs or EMOs is, however, poorly understood. Here we model equilibrium N and C partitioning between alloy and silicate melts in the absence (IMO) or presence (EMO) of vapor degassed atmospheres. Bulk N and C inventories of the protoplanets during core formation are constrained for IMOs and EMOs by comparing the predicted N and C abundances in the alloy melts from both scenarios with N and C concentrations in the parent cores of magmatic iron meteorites. Our results show that in comparison to EMOs, protoplanets having IMOs satisfy N and C contents of the parent cores with substantially lower amounts of bulk N and C present in the parent body during core formation. As the required bulk N and C contents for IMOs and EMOs are in the sub-chondritic and chondritic range, respectively, N and C fractionation models alone cannot be used to distinguish the prevalence of these two end-member differentiation regimes. A comparison of N and C abundances in chondrites with their peak metamorphic temperatures suggests that protoplanetary interiors could lose a substantial portion of their N and C inventories with increasing degrees of thermal metamorphism.

15. A HARPS radial velocity search for planets in the Scorpius-Centaurus association. And its combination with the HARPS and SOPHIE young nearby stars (YNS) surveys

Antoine Grandjean, A. -M. Lagrange, N. Meunier, G. Chauvin, S. Borgniet, S. Desidera, F. Galland, F. Kiefer, S. Messina, D. Iglesias, B. Nicholson, B. Pantoja, P. Rubini, E. Sedaghati, M. Sterzik, N. Zicher ★ The Scorpius-Centaurus (Sco-Cen) young and nearby massive star-forming region is particularly well suited for extrasolar planet searches with both direct imaging and radial velocity (RV) techniques. The RV search, however, is challenging, as the stars are faster rotators on average than their older stellar counterparts of similar spectral types. Moreover, the RV time series show strong signatures of stellar variability (spots and faculae) and/or stellar pulsations. Our aim is to search for giant planets (GPs) and brown dwarfs at short orbital distances around star members of the Sco-Cen association. We also aim at using these data together with others available on young stars to estimate the GP occurrence rate for young stars for periods of up to 1000 days. We used the HARPS spectrograph on the 3.6m telescope at the La Silla Observatory to monitor 88 A-F Sco-Cen stars. To improve our statistics and analysis, we combined this survey with two previous surveys that focused on young nearby stars (YNS) to compute companion occurrence rates from a sample of 176 young A-M stars. We report the discovery of a massive hot-Jupiter candidate around HD 145467, together with the discovery of one probable short-period (P < 10 days) brown dwarf around HD 149790. In addition, we confirm the binary nature of eight single-line binaries: HD 108857, HD 108904, HD 111102, HD 114319, HD 121176, HD 126488, HD 126838, and HD 133574. From our sample, we obtain a GP ($m_c \in [1; 13] M_{Jup}$) occurrence rate of $0.7^{+1.6}_{-0.2}$ % for periods between 1 and 1000 days and a brown dwarf ($m_c \in [13; 80] M_{Jup}$) occurrence rate of $0.6^{+1.4}_{-0.2}$ %, in the same period range. In addition, we report a possible lack of close ($P \in [1; 1000] days$) GPs around young F-K stars compared to their older counterparts, with a confidence level of 95%.

16. Searching for H_α-emitting sources in the gaps of five transitional disks. SPHERE/ZIMPOL high-contrast imaging

N. Huélamo, G. Chauvin, I. Mendigutía, E. Whelan, J. M. Alcalá, G. Cugno, H. M. Schmid, I. de Gregorio-Monsalvo, A. Zurlo, D. Barrado, M. Benisty, S. P. Quanz, H. Bouy, B. Montesinos, Y. Beletsky, J. Szulagyi ★ (Pre-)transitional disks show gaps and cavities that can be related with on-going planet formation. According to theory, young embedded planets can accrete material from the circumplanetary and circumstellar disks, so that they could be detected in accretion tracers, like the H_α emission line. In this work, we present spectral angular differential imaging AO-assisted observations of five (pre-)transitional disks obtained with SPHERE/ZIMPOL at the Very Large Telescope (VLT). They were obtained in the H_α line and the adjacent continuum. We have combined spectral and angular differential imaging techniques to increase the contrast in the innermost regions close to the star, and search for the signature of young accreting protoplanets. As a result, the reduced images do not show any clear H_α point source around any of the targets. We report faint H_α emissions around TW Hya and HD163296: while the former is most probably an artifact related with a spike, the nature of the latter remains unclear. The spectral and angular differential images yield contrasts of 6–8 magnitudes at separations of ~ 100 mas from the central stars, except in the case of LkCa15, with values of $\sim$3 mag. We have estimated upper limits to the accretion luminosity of potential protoplanets, obtaining that planetary models provide an average value of $L_{\rm acc} \sim 10^{-4}\ L_\odot$ at 200 mas, which is $\sim$2 orders of magnitude higher than the $L_{\rm acc}$ estimated from the extrapolation of the L_{H_α} - L_{acc} stellar relationship. We explain the lack of protoplanet detections as a combination of different factors, like e.g. episodic accretion, extinction from the circumstellar and circumplanetray disks, and/or a majority of low-mass, low-accreting planets.

17. The JCMT BISTRO Survey: A Spiral Magnetic Field in a Hub-Filament Structure, Monoceros R2

Jihye Hwang et al. ★ We present and analyze observations of polarized dust emission at 850 μm towards the central 1 pc $\times$ 1 pc hub-filament structure of Monoceros R2 (Mon R2). The data are obtained with SCUBA-2/POL-2 on the James Clerk Maxwell Telescope (JCMT) as part of the BISTRO (B-fields in Star-forming Region Observations) survey. The orientations of the magnetic field follow the spiral structure of Mon R2, which are well-described by an axisymmetric magnetic field model. We estimate the turbulent component of the magnetic field using the angle difference between our observations and the best-fit model of the underlying large-scale mean magnetic field. This estimate is used to calculate the magnetic field strength using the Davis-Chandrasekhar-Fermi method, for which we also obtain the distribution of volume density and velocity dispersion using a column density map derived from *Herschel* data and the $C^{18}O$ (J = 3-2) data taken with HARP on the JCMT, respectively. We make maps of magnetic field strengths and mass-to-flux ratios, finding that magnetic field strengths vary from 0.02 to 3.64 mG with a mean value of 1.0 $\pm$ 0.06 mG, and the mean critical mass-to-flux ratio is 0.47 $\pm$ 0.02. Additionally, the mean Alfvén Mach number is 0.35 $\pm$ 0.01. This suggests that in Mon R2, magnetic fields provide resistance against large-scale gravitational collapse, and magnetic pressure exceeds turbulent pressure. We also investigate the properties of each filament in Mon R2. Most of the filaments are aligned along the magnetic field direction and are magnetically sub-critical.

18. A survey for variable young stars with small telescopes: VII – Spot Properties on YSOs in IC5070

Carys Herbert, Dirk Froebrich, Aleks Scholz ★ We present measurements of spot properties on 31 young stellar objects, based on multi-band data from the HOYS (Hunting Outbursting Young Stars) project. On average the analysis for each object is based on 270 data points during 80 days in at least 3 bands. All the young low-mass stars in our sample show periodic photometric variations. We determine spot temperatures and coverage by comparing the measured photometric amplitudes in optical bands with simulated amplitudes based on atmosphere models, including a complete error propagation. 21 objects in our sample feature cool spots, with spot temperatures 500 - 2500 K below the stellar effective temperature ($T_{\rm eff}$), and a coverage of 0.05 - 0.4. Six more have hot spots, with temperatures up to 3000 K above $T_{\rm eff}$ and coverage below 0.15. The remaining four stars have ambiguous solutions or are AA Tau-type contaminants. All of the stars with large spots (i.e. high coverage > 0.1) are relatively cool with $T_{\rm eff} < 4500$ K, which could be a result of having deeper convection zones. Apart from that, spot properties show no significant trends with rotation period, infrared excess, or stellar properties. Most notably, we find hot spots in stars that do not show $K - W2$ infrared excess, indicating the possibility of accretion across an inner disk cavity or the presence of plage.

19. Saturation level of turbulence in collapsing gas clouds

Sho Higashi, Hajime Susa, Gen Chiaki ★ We investigate the physical mechanism that decides the saturation level of turbulence in collapsing gas clouds. We perform a suite of high-resolution numerical simulations following the collapse of turbulent gas clouds with various effective polytropic exponents $\gamma_{\rm eff}$, initial Mach numbers $\mathcal{M}_0$, and initial turbulent seeds. Equating the energy injection rate by gravitational contraction and the dissipation rate of turbulence, we obtain an analytic expression of the saturation level of turbulence, and compare it with the numerical results. Consequently, the numerical results are well described by the analytic model, given that the turbulent driving scale in collapsing gas clouds is one-third of Jeans length of collapsing core. These results indicate that the strength of turbulence at the first core formation in the early universe/present-day star-formation process can be estimated solely by $\gamma_{\rm eff}$.

20. How magnetic field and stellar radiative feedback influences the collapse and the stellar mass spectrum of a massive star forming clump

Patrick Hennebelle, Ugo Lebreuilly, Tine Colman, Davide Elia, Gary Fuller, Silvia Leurini, Thomas Nony, Eugenio Schisano, Juan D. Soler, Alessio Traficante, Ralf S. Klessen, Sergio Molinari, Leonardo Testi ★ In spite of decades of theoretical efforts, the physical origin of the stellar initial mass function (IMF) is still debated. We aim at understanding the influence of various physical processes such as radiative stellar feedback, magnetic field and non-ideal magneto-hydrodynamics on the IMF. We present a series of numerical simulations of collapsing 1000 $M_\odot$ clumps taking into account radiative feedback and magnetic field with spatial resolution down to 1 AU. Both ideal and non-ideal MHD runs are performed and various radiative feedback efficiencies are considered. We also develop analytical models that we confront to the numerical results. The sum of the luminosities produced by the stars in the calculations is computed and it compares well with the bolometric luminosities reported in observations of massive star forming clumps. The temperatures, velocities and densities are also found to be in good agreement with recent observations. The stellar mass spectrum inferred for the simulations is, generally speaking, not strictly universal and in particular varies with magnetic intensity. It is also influenced by the choice of the radiative feedback efficiency. In all simulations, a sharp drop in the stellar distribution is found at about $M_{min} \simeq 0.1$ $M_\odot$, which is likely a consequence of the adiabatic behaviour induced by dust opacities at high densities. As a consequence, when the combination of magnetic and thermal support is not too large, the mass distribution presents a peak located at 0.3-0.5 $M_\odot$.

When magnetic and thermal support are large, the mass distribution is better described by a plateau, i.e. $dN/d\log M \propto M^{-\Gamma}$, $\Gamma \simeq 0$. Abridged

21. The Exoplanet Radius Valley from Gas-driven Planet Migration and Breaking of Resonant Chains

Andre Izidoro, Hilke E. Schlichting, Andrea Isella, Rajdeep Dasgupta, Christian Zimmermann, Bertram Bitsch ★ The size frequency distribution of exoplanet radii between 1 and $4R_\oplus$ is bimodal with peaks at $\sim$1.4 $R_\oplus$ and $\sim$2.4 $R_\oplus$, and a valley at $\sim 1.8R_\oplus$. This radius valley separates two classes of planets – usually referred to as "super-Earths" and "mini-Neptunes" – and its origin remains debated. One model proposes that super-Earths are the outcome of photo-evaporation or core-powered mass-loss stripping the primordial atmospheres of the mini-Neptunes. A contrasting model interprets the radius valley as a dichotomy in the bulk compositions, where super-Earths are rocky planets and mini-Neptunes are water-ice rich worlds. In this work, we test whether the migration model is consistent with the radius valley and how it distinguishes these views. In the migration model, planets migrate towards the disk inner edge forming a chain of planets locked in resonant configurations. After the gas disk dispersal, orbital instabilities "break the chains" and promote late collisions. This model broadly matches the period-ratio and planet-multiplicity distributions of Kepler planets, and accounts for resonant chains such as TRAPPIST-1, Kepler-223, and TOI-178. Here, by combining the outcome of planet formation simulations with compositional mass-radius relationships, and assuming complete loss of primordial H-rich atmospheres in late giant-impacts, we show that the migration model accounts for the exoplanet radius valley and the intra-system uniformity ("peas-in-a-pod") of Kepler planets. Our results suggest that planets with sizes of $\sim$1.4 $R_\oplus$ are mostly rocky, whereas those with sizes of $\sim$2.4 $R_\oplus$ are mostly water-ice rich worlds. Our results do not support an exclusively rocky composition for the cores of mini-Neptunes.

22. Filament Formation via Collision-induced Magnetic Reconnection – Formation of a Star Cluster

Shuo Kong, David Whitworth, Rowan J. Smith, Erika T. Hamden ★ A collision-induced magnetic reconnection (CMR) mechanism was recently proposed to explain the formation of a filament in the Orion A molecular cloud. In this mechanism, a collision between two clouds with antiparallel magnetic fields produces a dense filament due to the magnetic tension of the reconnected fields. The filament contains fiber-like sub-structures and is confined by a helical magnetic field. To show whether the dense filament is capable of forming stars, we use the Arepo code with sink particles to model star formation following the formation of the CMR-filament. First, the CMR-filament formation is confirmed with Arepo. Second, the filament is able to form a star cluster after it collapses along its main axis. Compared to the control model without magnetic fields, the CMR model shows two distinctive features. First, the CMR-cluster is confined to a factor of $\sim$ 4 smaller volume. The confinement is due to the combination of the helical field and gravity. Second, the CMR model has a factor of $\sim$ 2 lower star formation rate. The slower star formation is again due to the surface helical field that hinders gas inflow from larger scales. Mass is only supplied to the accreting cluster through streamers.

23. Evidence of a signature of planet formation processes from solar neutrino fluxes

Masanobu Kunitomo, Tristan Guillot, Gaël Buldgen ★ Solar evolutionary models are thus far unable to reproduce spectroscopic, helioseismic, and neutrino constraints consistently, resulting in the so-called solar modeling problem. In parallel, planet formation models predict that the evolving composition of the protosolar disk and, thus, of the gas accreted by the proto-Sun must have been variable. We show that solar evolutionary models that include a realistic planet formation scenario lead to an increased core metallicity of up to 5%, implying that accurate neutrino flux measurements are sensitive to the initial stages of the formation of the Solar System. Models with homogeneous accretion match neutrino constraints to no better than 2.7σ. In contrast, accretion with a variable composition due to planet formation processes, leading to metal-poor accretion of the last $\sim$4% of the young Sun's total mass, yields solar models within 1.3σ of all neutrino constraints. We thus demonstrate that in addition to increased opacities at the base of the convective envelope, the formation history of the Solar System constitutes a key element in resolving the current crisis of solar models.

24. A Multi-Scale Picture of Magnetic Field and Gravity from Large-Scale Filamentary Envelope to Core-Accreting Dust Lanes in the High-Mass Star-Forming Region W51

Patrick M. Koch, Ya-Wen Tang, Paul T. P. Ho, Pei-Ying Hsieh, Jia-Wei Wang, Hsi-Wei Yen, Ana Duarte-Cabral, Nicolas Peretto, Yu-Nung Su ★ We present 230 GHz continuum polarization observations with the Atacama Large Milimeter/Submillimeter Array (ALMA) at a resolution of 0.1 arcseconds ($\sim$ 540 au) in the high-mass star-forming regions W51 e2 and e8. These observations resolve a network of core-connecting dust lanes, marking a departure from earlier coarser more spherical continuum structures. At the same time, the cores do not appear to fragment further. Polarized dust emission is clearly detected. The inferred magnetic field orientations are prevailingly parallel to dust lanes. This key structural feature is analyzed together with the local gravitational vector field. The direction of local gravity is found to typically align with dust lanes. With these findings we derive a stability criterion that defines a maximum magnetic field strength that can be overcome by an observed magnetic field-gravity configuration. Equivalently, this defines a minimum field strength that can stabilize dust lanes against a radial collapse. We find that the detected dust lanes in W51 e2 and e8 are stable, hence possibly making them a fundamental component in the accretion onto central sources, providing support for massive star formation models without the need of large accretion disks. When comparing to coarser resolutions, covering the scales of envelope, global, and local collapse, we find recurring similarities in the magnetic field structures and their corresponding gravitational vector fields. These self-similar structures point at a multi-scale collapse-within-collapse scenario until finally the scale of core-accreting dust lanes is reached where gravity is entraining the magnetic field and aligning it with the dust lanes.

25. On the underestimation of dust mass in protoplanetary disks: Effects of disk structure and dust properties

Yao Liu, Hendrik Linz, Min Fang, Thomas Henning, Sebastian Wolf, Mario Flock, Giovanni P. Rosotti, Hongchi Wang, Dafa Li ★ The total amount of dust grains in protoplanetary disks is one of the key properties that characterize the potential for planet formation. With (sub-)millimeter flux measurements, literature studies usually derive the dust mass using an analytic form under the assumption of optically thin emission, which may lead to substantial underestimation. In this work, we conduct a parameter study with the goal of investigating the effects of disk structure and dust properties on the underestimation through self-consistent radiative transfer models. Different dust models, scattering modes and approaches for dust settling are considered and compared. The influences of disk substructures, such as rings and crescents, on the mass derivation are investigated as well. The results indicate that the traditional analytic method can underestimate the mass by a factor of a few to hundreds, depending on the optical depth along the line of sight set mainly by the true dust mass, disk size and inclination. As an application, we perform a detailed radiative transfer modeling of the spectral energy distribution of DoAr 33, one of the observed DSHARP disks. When the DSHARP dust opacities are adopted, the most probable dust mass returned from the Bayesian analysis is roughly 7 times higher than the value given by the analytic calculation. Our study demonstrates that estimating disk dust masses from radiative transfer modeling is one solution for alleviating the problem of insufficient mass for planet formation raised in the ALMA era.

26. The effect of collisional erosion on the composition of Earth-analog planets in Grand Tack models: Implications for the formation of the Earth

Allibert L., Siebert J., Charnoz S., Jacobson S. A., Raymond S. N ★ Impact-induced erosion of the Earth's early crust during accretion of terrestrial bodies can significantly modify the primordial chemical composition of the Bulk Silicate Earth (BSE, that is, the composition of the crust added to the present-day mantle). In particular, it can be particularly efficient in altering the abundances of elements having a strong affinity for silicate melts (i.e. incompatible elements) as the early differentiated crust was preferentially enriched in those. Here, we further develop an erosion model (EROD) to quantify the effects of collisional erosion on the final composition of the BSE. Results are compared to the present-day BSE composition models and constraints on Earth's accretion processes are provided. The evolution of the BSE chemical composition resulting from crustal stripping is computed for entire accretion histories of about 50 Earth analogs in the context of the Grand Tack model. The chosen chemical elements span a wide range of incompatibility degrees. We find that a maximum loss of 40wt% can be expected for the most incompatible lithophile elements such as Rb, Th or U in the BSE when the crust is formed from low partial melting rates. Accordingly, depending on both the exact nature of the crust-forming processes during accretion and the accretion history itself, Refractory Lithophile Elements (RLE) may not be in chondritic relative proportions in the BSE. In that case, current BSE estimates may need to be corrected as a function of the geochemical incompatibility of these elements. Alternatively, if RLE are indeed in chondritic relative proportions in the BSE, accretion scenarios that are efficient in affecting the BSE chemical composition should be questioned.

27. Stellar population of the Rosette Nebula and NGC 2244: application of the probabilistic random forest

Koraljka Muzic, Victor Almendros-Abad, Herve Bouy, Karolina Kubiak, Karla Pena Ramirez, Alberto Krone-Martins, Andre Moitinho, Miguel Conceicao ★ (Abridged) In this work, we study the 2.8x2.6 deg2 region in the emblematic Rosette Nebula, centred at the young cluster NGC 2244, with the aim of constructing the most reliable candidate member list to date, determining various structural and kinematic parameters, and learning about the past and the future of the region. Starting from a catalogue containing optical to mid-infrared photometry, as well as positions and proper motions from Gaia EDR3, we apply the Probabilistic Random Forest algorithm and derive membership probability for each source. Based on the list of almost 3000 probable members, of which about a third are concentrated within the radius of 20' from the centre of NGC 2244, we identify various clustered sources and stellar concentrations, and estimate the average distance of 1489+-37 pc (entire region), 1440+-32 pc (NGC 2244) and 1525+-36 pc (NGC 2237). The masses, extinction, and ages are derived by SED fitting, and the internal dynamic is assessed via proper motions relative to the mean proper motion of NGC 2244. NGC 2244 is showing a clear expansion pattern, with an expansion velocity that increases with radius. Its IMF is well represented by two power laws (dN/dM$\propto$ M$^{-\alpha}$), with slopes α = 1.05+-0.02 for the mass range 0.2 - 1.5 MSun, and α = 2.3+-0.3 for the mass range 1.5 - 20 MSun, in agreement with other star forming regions. The mean age of the region is 2 Myr. We find evidence for the difference in ages between NGC 2244 and the region associated with the molecular cloud, which appears slightly younger. The velocity dispersion of NGC 2244 is well above the virial velocity dispersion derived from the total mass (1000+-70 MSun) and half-mass radius (3.4+-0.2 pc). From the comparison to other clusters and to numerical simulations, we conclude that NGC 2244 may be unbound, and possibly even formed in a super-virial state.

28. Long-term Photometric Study of the Pre-main Sequence Star V1180 Cas

Asen Mutafov, Evgeni Semkov, Stoyanka Peneva, Sunay Ibryamov ★ In this paper results from the optical photometric observations of the pre-main-sequence star V1180 Cas are reported. The star is a young variable associated with the dark cloud Lynds 1340, located at a distance of 600 pc from the Sun in the star forming region in Cassiopeia. V1180 Cas shows a large amplitude variability interpreted as a combination of accretion-induced and extinction-driven effects. Our data from VRI CCD photometric observations of the star are collected from September 2011 to February 2022. During our monitoring, we recorded several brightness dips with large amplitudes of up to 5 mag. (I-band). At the same time, increases in brightness over periods of several weeks have also been recorded. In this paper, we compare the photometric data obtained for V1180 Cas with observations of other low-mass pre-main sequence objects.

29. The burst mode of accretion in massive star formation with stellar inertia

D. M. -A. Meyer, E. I. Vorobyov, V. G. Elbakyan, S. Kraus, S. -Y. Liu, S. Nayakshin, A. M. Sobolev ★ The burst mode of accretion in massive star formation is a scenario linking the initial gravitational collapse of parent pre-stellar cores to the properties of their gravitationally unstable discs and of their accretion-driven bursts. In this study, we present a series of high-resolution 3D radiation-hydrodynamics numerical simulations for young massive stars formed out of collapsing 100 Mo molecular cores spinning with several values of the ratio of rotational-to-gravitational energies beta=5%-9%. The models include the indirect gravitational potential caused by disc asymmetries. We find that this modifies the barycenter of the disc, causing significant excursions of the central star position, which we term stellar wobbling. The stellar wobbling slows down and protracts the development of gravitational instability in the disc, reducing the number and magnitude of the accretion-driven bursts undergone by the young massive stars, whose properties are in good agreement with that of the burst monitored from the massive protostar M17 MIR. Including stellar wobbling is therefore important for accurate modeling disc structures. Synthetic ALMA interferometric images in the millimeter waveband show that the outcomes of efficient gravitational instability such as spiral arms and gaseous clumps can be detected for as long as the disc is old enough and has already entered the burst mode of accretion.

30. Infrared Spectroscopic Survey of the Quiescent Medium of Nearby Clouds: II. Ice Formation and Grain Growth in Perseus and Serpens

M. C. L. Madden, A. C. A. Boogert, J. E. Chiar, C. Knez, Y. J. Pendleton, A. G. G. M. Tielens, A. Yip ★ The properties of dust change during the transition from diffuse to dense clouds as a result of ice formation and dust coagulation, but much is still unclear about this transformation. We present 2-20 micron spectra of 49 field stars behind the Perseus and Serpens Molecular Clouds and establish relationships between the near-infrared continuum extinction (AK) and the depths of the 9.7 micron silicate (tau97) and 3.0 micron H2O ice (tau30) absorption bands. The tau97/AK ratio varies from large, diffuse interstellar medium-like values (0.55), to much lower ratios (0.26). Above extinctions of AK 1.2 (AV 10; Perseus, Lupus, dense cores) and 2.0 (AV 17; Serpens), the tau97/AK ratio is lowest. The tau97/AK reduction from diffuse to dense clouds is consistent with a moderate degree of grain growth (sizes up to 0.5 micron), increasing the near-infrared color excess (and thus AK), but not affecting ice and silicate band profiles. This grain growth process seems to be related to the ice column densities and dense core formation thresholds, highlighting the importance of density. After correction for Serpens foreground extinction, the H2O ice formation threshold is in the range of AK=0.31-0.40 (AV=2.6-3.4) for all clouds, and thus grain growth takes place after the ices are formed. Finally, abundant CH3OH ice (21% relative to H2O) is reported for 2MASSJ18285266+0028242 (Serpens), a factor of >4 larger than for the other targets.

31. Modeling disks and magnetic outflows around a forming massive star: II. Dynamics of jets from massive protostars

André Oliva, Rolf Kuiper ★ Forming massive stars launch outflows of magnetic origin, which in fact serve as a marker for finding sites of massive star formation. However, both the theoretical and observational study of the mechanisms that intervene in the formation and propagation of such outflows has been possible only until recent years. With this work, we aim to study in detail the mechanisms that drive highly collimated outflows from early stages of the formation of a massive star, and how those processes are impacted by the properties of the natal environment of the forming massive star. We perform a series of 31 simulations with the aim of building a unified theoretical picture of these mechanisms, and see how the impact of different environments alter their morphology and momentum output. The magnetohydrodynamical simulations consider also Ohmic dissipation as a nonideal effect, self-gravity, and diffusive radiation transport for thermal absorption and emission by the dust and gas. We start from a collapsing cloud core that is threaded by an initially-uniform magnetic field and which is slowly rotating. We utilize a two-dimensional axisymmetric grid in spherical coordinates. In the simulations, we can clearly distinguish a fast, magneto-centrifugally launched and collimated jet (of speeds > 100 km/s), from a wider magnetic tower flow driven by magnetic pressure which broadens in time. We analyze in detail the acceleration of the flow, and its re-collimation by magnetic forces happening at distances of several hundreds of astronomical units. We quantify the impact of magnetic braking in the outflows, which narrows the outflow cavity for the late evolution of the system. We observe the presence of the same jet-driving mechanisms for a wide range of assumptions on the natal environment of the massive protostar, but with changes to their morphology and mechanical feedback into larger scales over time.

32. Infrared variability of young solar analogs in the Lagoon Nebula

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

33. On the evolution of pebble-accreting planets in evolving protoplanetary discs

Arnaud Pierens ★ We examine the migration of luminous low-mass cores in laminar protoplanetary discs where accretion occurs mainly because of disc winds and where the planet luminosity is generated by pebble accretion. Using 2D hydrodynamical simulations, we determine the eccentricities induced by thermal forces as a function of gas and pebble accretion rates, and also evaluate the importance of the torque exerted by the solid component relative to the gas torque. For a gas accretion rate $\dot{M} = 2 \times 10^{-8}\ M_\odot$/yr and pebble flux $\dot{M}_{peb} = 170\ M_\oplus$/Myr, we find that embryo eccentricities attain values comparable to the disc aspect ratio. The planet radial excursion in the disc, however, causes the torque exerted by inflowing pebbles to cancel on average and migration to transition from outward to inward. This is found to arise because the magnitude of thermal torques decreases exponentially with increasing eccentricity, and we provide a fitting formula for the thermal torque attenuation as a function of eccentricity. As the disc evolves, the accretion luminosity becomes at some point too small to make the core eccentricity grow such that the solid component can exert a non-zero torque on the planet. This torque is positive and for gas accretion rates $\dot{M} \lesssim 5 \times 10^{-9}\ M_\odot$/yr and pebble fluxes $\dot{M}_{peb} \lesssim 120\ M_\oplus$/Myr, it is found to overcome the gas torque exerted on cores with mass $m_p \lesssim 1 M_\oplus$, resulting in outward migration.

34. Directly tracing the vertical stratification of molecules in protoplanetary disks

T. Paneque-Carreño, A. Miotello, E. F. van Dishoeck, B. Tabone, A. F. Izquierdo, S. Facchini ★ We aim to directly trace the vertical location of the emitting surface of multiple molecular tracers in protoplanetary disks. Our sample of disks includes Elias 2-27, WaOph 6 and the sources targeted by the MAPS ALMA Large Program. The set of molecules studied include CO isotopologues in various transitions, HCN, CN, H2CO, HCO+, C2H and c-C3H2. The vertical emitting region is determined directly from the channel maps, implementing accurate masking of the channel emission to recover the vertical location of the emission surface even at large radial distances from the star and for low-SNR lines. The vertical location of the emitting layer is obtained for 4-10 lines in each disk. IM Lup, HD163296 and MWC 480 12CO and 13CO show vertical modulations, which are coincident with dust gaps and kinematical perturbations. We also present estimates of the gas pressure scale height in the disks from the MAPS sample. Compared to physical-chemical models we find good agreement with the vertical location of CO isotopologues. In HD 163296 CN and HCN trace a similar intermediate layer, for the other disks, the UV flux tracers and the vertical profiles of HCN and C2H are lower than predicted in theoretical models. HCN and H2CO show a highly structured vertical profile, possibly indicative of different formation pathways. It is possible to trace the vertical locations of multiple molecular species that trace a wide variety of physical and chemical disk properties. The distribution of CO isotopologues are found at a wide range of vertical heights z/r = 0.5-0.05. Other molecular lines are mostly found at

$z/r \leq 0.15$. The vertical layering of molecules is in agreement with theory in some systems, but not in all, therefore dedicated chemical-physical models are needed to further study and understand the emission surfaces.

35. Most planets might have more than 5 Myr of time to form

Susanne Pfalzner, Shahrzad Dehghani, Arnaud Michel ★ The lifetime of protoplanetary disks is a crucial parameter for planet formation research. Observations of disk fractions in star clusters imply median disk lifetimes of 1 – 3 Myr. This very short disk lifetime calls for planet formation to occur extremely rapidly. We show that young, distant clusters ($\leq$ 5 Myr, $>$ 200 pc) often dominate these types of studies. Such clusters frequently suffer from limiting magnitudes leading to an over-representation of high-mass stars. As high-mass stars disperse their disks earlier, the derived disk lifetimes apply best to high-mass stars rather than low-mass stars. Including only nearby clusters ($<$ 200 pc) minimizes the effect of limiting magnitude. In this case, the median disk lifetime of low-mass stars is with 5 – 10 Myr, thus much longer than often claimed. The longer timescales provide planets ample time to form. How high-mass stars form planets so much faster than low-mass stars is the next grand challenges.

36. 12CO (3-2) High-Resolution Survey (COHRS) of the Galactic Plane: Complete Data Release

Geumsook Park, Malcolm J. Currie, Holly S. Thomas, Erik Rosolowsky, Jessica T. Dempsey, Kee-Tae Kim, Andrew J. Rigby, Yang Su, David J. Eden, Dario Colombo, Harriet Parsons, Toby J. T. Moore ★ We present the full data release of 12CO (3-2) High-Resolution Survey (COHRS), which has mapped the inner Galactic plane over the range of $9.5^\circ \leq l \leq 62.3^\circ$ and $|b| \leq 0.5^\circ$. The COHRS has been carried out using the Heterodyne Array Receiver Program (HARP) on the 15 m James Clerk Maxwell Telescope (JCMT) in Hawaii. The released data are smoothed to have a spatial resolution of 16.6 arcsec and a velocity resolution of 0.635 km/s, achieving a mean root-mean-square of $\sim$ 0.6 K on $T_{\rm A}^*$. The COHRS data are useful for investigating detailed three-dimensional structures of individual molecular clouds and large-scale structures such as spiral arms in the Galactic plane. Furthermore, data from other available public surveys of different CO isotopologues and transitions with similar angular resolutions to this survey, such as FUGIN, SEDIGISM, and CHIMPS/CHIMPS2, allow studying the physical properties of molecular clouds and comparing their states with each other. In this paper, we report further observations on R2 and improved data reduction since the original COHRS release. We discuss the characteristics of the COHRS data and present integrated-emission images and a position-velocity (PV) map of the region covered. The PV map shows a good match with the spiral-arm traces from the existing CO and HI surveys. We also obtain and compare integrated one-dimensional distributions of 12CO (1-0) and (3-2) and those of star-forming populations to each other.

37. First Steps of Planet Formation Around Very Low Mass Stars and Brown Dwarfs

Paola Pinilla ★ Brown dwarfs and very low mass stars are a significant fraction of stars in our galaxy, and they are interesting laboratories to investigate planet formation in extreme conditions of low temperature and densities. In addition, the dust radial drift of particles is expected to be a more difficult barrier to overcome during the first steps of planet formation in these disks. ALMA high-angular resolution observations of few protoplanetary disks around BDs and VLMS have shown substructures as in the disks around Sun-like stars. Such observations suggest that giant planets embedded in the disks are the most likely origin of the observed substructures. However, this type of planets represent less than 2% of the confirmed exoplanets so far around all stars, and they are difficult to form by different core accretion models (either pebble or planetesimal accretion). Dedicated deep observations of disks around BDs and VLMS with ALMA and JWST will provide significant progress on understanding the main properties of these objects (e.g., disk size and mass), which is crucial for determining the physical mechanisms that rule the evolution of these disks and the effect on the potential planets that may form in these environments.

38. Star formation in IC1396: Kinematics and subcluster structure revealed by Gaia

Mara E. Pelayo-Baldárrago, Aurora Sicilia-Aguilar, Min Fang, Veronica Roccatagliata, Jinyoung Serena Kim, David García-Álvarez ★ We investigate the star formation history of the IC1396 region by studying its kinematics and completing the population census. We use multiwavelength data, combining optical spectroscopy (to identify and classify new members), near-infrared photometry (to trace shocks, jets, and outflows and the interactions between the cluster members and the cloud), along with Gaia EDR3 to identify new potential members in the multidimensional proper motion/parallax space. The revised Gaia EDR3 distance is 925$\pm$73 pc, slightly closer than previously obtained with DR2. The Gaia data reveal four distinct subclusters in the region. These subclusters are consistent in distance but display differences in proper motion. This, with their age differences, hints towards a complex and varied star formation history. Gaia data also unveil the intermediate-mass objects that tend to evade spectroscopic and disk surveys. Our analysis allows us to identify 334 new members. We estimate an average age of $\sim$4 Myr, confirming previous age estimates. With the new members added to our study, we estimate a disk fraction of 28%, lower than previous values, due to our method detecting mainly new, diskless intermediate-mass stars. We find age differences between the subclusters, which evidences a complex star formation history with different episodes of star formation.

39. Deep diving off the 'Cosmic Cliffs': previously hidden outflows in NGC 3324 revealed by JWST

Megan Reiter, Jon A. Morse, Nathan Smith, Thomas J. Haworth, Michael A. Kuhn, Pamela D. Klaassen ★ We present a detailed analysis of the protostellar outflow activity in the massive star-forming region NGC 3324, as revealed by new Early Release Observations (ERO) from the James Webb Space Telescope (JWST). Emission from numerous outflows is revealed in narrow-band images of hydrogen Paschen-α (Pa-α) and molecular hydrogen. In particular, we report the discovery of 24 previously unknown outflows based on their H_2 emission. We find three candidate driving sources for these H_2 flows in published catalogs of young stellar objects (YSOs) and we identify 15 IR point sources in the new JWST images as potential driving protostars. We also identify several Herbig-Haro (HH) objects in Pa-α images from JWST; most are confirmed as jets based on their proper motions measured in a comparison with previous Hubble Space Telescope (HST) Hα images. This confirmed all previous HST-identified HH jets and candidate jets, and revealed 7 new HH objects. The unprecedented capabilities of JWST allow the direct comparison of atomic and molecular outflow components at comparable angular resolution. Future observations will allow quantitative analysis of the excitation, mass-loss rates, and velocities of these new flows. As a relatively modest region of massive star formation (larger than Orion but smaller than starburst clusters), NGC 3324 offers a preview of what star formation studies with JWST may provide.

40. Star formation timescale in the molecular filament WB 673

O. L. Ryabukhina, M. S. Kirsanova, C. Henkel, D. S. Wiebe ★ We present observations of ammonia emission lines toward the interstellar filament WB 673 hosting the dense clumps WB 673, WB 668, S233-IR and G173.57+2.43. LTE analysis of the lines allows us to estimate gas kinetic temperature ($\lesssim$ 30 K in all the clumps), number density ($7 - 17 \times 10^3$ cm^{-3}), and ammonia column density ($\approx 1 - 1.5 \times 10^{15}$ cm^{-2}) in the dense clumps. We find signatures of collapse in WB 673 and presence of compact spatially unresolved dense clumps in S233-IR. We reconstruct 1D density and temperature distributions in the clumps and estimate their ages using astrochemical modelling. Considering CO, CS, NH_3 and N_2H^+ molecules (plus HCN and HNC for WB 673), we find a chemical age of $t_{\rm chem} = 1 - 3 \times 10^5$ yrs providing the best agreement between the simulated and observed column densities in all the clumps. Therefore, we consider $t_{\rm chem}$ as the chemical age of the entire filament. A long preceding low-density stage of gas accumulation in the astrochemical model would break the agreement between the simulated and observed column densities. We suggest that rapid star formation over a $\sim 10^5$ yrs timescale take place in the filament.

41. The ALMA Survey of 70 μm Dark High-mass Clumps in Early Stages (ASHES). VI. The core-scale CO-depletion

Giovanni Sabatini, Stefano Bovino, Patricio Sanhueza, Kaho Morii, Shanghuo Li, Elena Redaelli, Qizhou Zhang, Xing Lu, Siyi Feng, Daniel Tafoya, Natsuko Izumi, Takeshi Sakai, Kenichi Tatematsu, David Allingham ★ Studying the physical and chemical properties of cold and dense molecular clouds is crucial for the understanding of how stars form. Under the typical conditions of infrared dark clouds, CO is removed from the gas phase and trapped on to the surface of dust grains by the so-called depletion process. This suggests that the CO depletion factor ($f_{\rm D}$) can be a useful chemical indicator for identifying cold and dense regions (i.e., prestellar cores). We have used the 1.3 mm continuum and $C^{18}O$(2-1) data observed at the resolution of ~5000 au in the ALMA Survey of 70 μm Dark High-mass Clumps in Early Stages (ASHES) to construct averaged maps of $f_{\rm D}$ in twelve clumps to characterise the earliest stages of the high-mass star formation process. The average $f_{\rm D}$ determined for 277 of the 294 ASHES cores follows an unexpected increase from the prestellar to the protostellar stage. If we exclude the temperature effect due to the slight variations in the NH_3 kinetic temperature among different cores, we explain this result as a dependence primarily on the average gas density, which increases in cores where protostellar conditions prevail. This shows that $f_{\rm D}$ determined in high-mass star-forming regions at the core scale is insufficient to distinguish among prestellar and protostellar conditions for the individual cores, and should be complemented by information provided by additional tracers. However, we confirm that the clump-averaged $f_{\rm D}$ values correlates with the luminosity-to-mass ratio of each source, which is known to trace the evolution of the star formation process.

42. The ALMA Survey of 70 μm Dark High-mass Clumps in Early Stages (ASHES). VI. The core-scale CO-depletion

Giovanni Sabatini, Stefano Bovino, Patricio Sanhueza, Kaho Morii, Shanghuo Li, Elena Redaelli, Qizhou Zhang, Xing Lu, Siyi Feng, Daniel Tafoya, Natsuko Izumi, Takeshi Sakai, Kenichi Tatematsu, David Allingham ★ Studying the physical and chemical properties of cold and dense molecular clouds is crucial for the understanding of how stars form. Under the typical conditions of infrared dark clouds, CO is removed from the gas phase and trapped on to the surface of dust grains by the so-called depletion process. This suggests that the CO depletion factor ($f_{\rm D}$) can be a useful chemical indicator for identifying cold and dense regions (i.e., prestellar cores). We have used the 1.3 mm continuum and $C^{18}O$(2-1) data observed

at the resolution of ∼5000 au in the ALMA Survey of 70 μm Dark High-mass Clumps in Early Stages (ASHES) to construct averaged maps of f_D in twelve clumps to characterise the earliest stages of the high-mass star formation process. The average f_D determined for 277 of the 294 ASHES cores follows an unexpected increase from the prestellar to the protostellar stage. If we exclude the temperature effect due to the slight variations in the NH_3 kinetic temperature among different cores, we explain this result as a dependence primarily on the average gas density, which increases in cores where protostellar conditions prevail. This shows that f_D determined in high-mass star-forming regions at the core scale is insufficient to distinguish among prestellar and protostellar conditions for the individual cores, and should be complemented by information provided by additional tracers. However, we confirm that the clump-averaged f_D values correlates with the luminosity-to-mass ratio of each source, which is known to trace the evolution of the star formation process.

43. Chemistry and dynamics of the prestellar core L1544

O. Sipilä, P. Caselli, E. Redaelli, S. Spezzano ★ We aim to quantify the effect of chemistry on the infall velocity in the prestellar core L1544. Previous observational studies have found evidence for double-peaked line profiles for the rotational transitions of several molecules, which cannot be accounted for with the models presently available for the physical structure of the source, without ad hoc up-scaling of the infall velocity. We ran one-dimensional hydrodynamical simulations of the collapse of a core with L1544-like properties (in terms of mass and outer radius), using a state-of-the-art chemical model with a very large chemical network combined with an extensive description of molecular line cooling, determined via radiative transfer simulations, with the aim of determining whether these expansions of the simulation setup (as compared to previous models) can lead to a higher infall velocity. After running a series of simulations where the simulation was sequentially simplified, we found that the infall velocity is almost independent of the size of the chemical network or the approach to line cooling. We conclude that chemical evolution does not have a large impact on the infall velocity, and that the higher infall velocities that are implied by observations may be the result of the core being more dynamically evolved than what is now thought, or alternatively the average density in the simulated core is too low. However, chemistry does have a large influence on the lifetime of the core, which varies by about a factor of two across the simulations and grows longer when the chemical network is simplified. Therefore, although the model is subject to several sources of uncertainties, the present results clearly indicate that the use of a small chemical network leads to an incorrect estimate of the core lifetime, which is naturally a critical parameter for the development of chemical complexity in the precollapse phase.

44. Dust grains cannot grow to millimeter sizes in protostellar envelopes

Kedron Silsbee, Vitaly Akimkin, Alexei V. Ivlev, Leonardo Testi, Munan Gong, Paola Caselli ★ A big question in the field of star and planet formation is the time at which substantial dust grain growth occurs. The observed properties of dust emission across different wavelength ranges have been used as an indication that millimeter-sized grains are already present in the envelopes of young protostars. However, this interpretation is in tension with results from coagulation simulations, which are not able to produce such large grains in these conditions. In this work, we show analytically that the production of millimeter-sized grains in protostellar envelopes is impossible under the standard assumptions about the coagulation process. We discuss several possibilities that may serve to explain the observed dust emission in the absence of in-situ grain growth to millimeter sizes.

45. Stellar Flyby Analysis for Spiral Arm Hosts with Gaia DR3

Linling Shuai, Bin B. Ren, Ruobing Dong, Xingyu Zhou, Laurent Pueyo, Robert J. De Rosa, Taotao Fang, Dimitri Mawet ★ Scattered light imaging studies have detected nearly two dozen spiral arm systems in circumstellar disks, yet the formation mechanisms for most of them are still under debate. Although existing studies can use motion measurements to distinguish leading mechanisms such as planet-disk interaction and disk self-gravity, close-in stellar flybys can induce short-lived spirals and even excite arm-driving planets into highly eccentric orbits. With unprecedented stellar location and proper motion measurements from Gaia DR3, here we study for known spiral arm systems their flyby history with their stellar neighbours by formulating an analytical on-sky flyby framework. For stellar neighbors currently located within 10 pc from the spiral hosts, we restrict the flyby time to be within the past 10^4 yr and the flyby distance to be within 10 times the disk extent in scattered light. Among a total of 12570 neighbors that are identified in Gaia DR3 for 20 spiral systems, we do not identify credible flyby candidates for isolated systems. Our analysis suggests that close-in recent flyby is not the dominant formation mechanism for isolated spiral systems in scattered light.

46. Using debris disk observations to infer substellar companions orbiting within or outside a parent planetesimal belt

T. A. Stuber, T. Löhne, S. Wolf ★ Aims. We analyze whether the effects of secular perturbations, originating from a substellar companion, on the dust dynamics in a debris disk can be investigated with spatially resolved observations. Methods. We numerically simulated the collisional evolution of narrow and eccentric cold planetesimal belts around a star of spectral type A3V that are secularly perturbed by a companion that orbits either closer to or farther from the star than the belt. Based on the resulting spatial dust distributions, we simulated spatially resolved maps of their surface brightness in the K, N, and Q bands and at wavelengths of 70μm and 1300μm. Results. Assuming a nearby debris disk seen face-on, we find that the brightness distribution varies significantly with observing wavelength, for example between the N and Q band. This can be explained by the varying relative contribution of the emission of the smallest grains near the blowout limit. The orbits of both the small grains that form the halo and the large grains close to the parent belt precess due to the secular perturbations induced by a companion orbiting inward of the belt. The halo, being composed of older grains, trails the belt. The magnitude of the trailing decreases with increasing perturber mass and hence with increasing strength of the perturbation, a trend we recovered in synthetic maps of surface brightness by fitting ellipses to lines of constant brightness. Systems with an outer perturber do not show a uniform halo precession since the orbits of small grains are strongly altered. We identified features of the brightness distributions suitable for distinguishing between systems with a potentially detectable inner or outer perturber, especially with a combined observation with JWST/MIRI in the Q band tracing small grain emission and with ALMA at mm wavelengths tracing the position of the parent planetesimal belt.

47. Nonlinear Outcome of Coagulation Instability in Protoplanetary Disks II: Dust Ring Formation Mediated by Backreaction and Fragmentation

Ryosuke T. Tominaga, Hidekazu Tanaka, Hiroshi Kobayashi, Shu-ichiro Inutsuka ★ In our previous work (Paper I), we demonstrated that coagulation instability results in dust concentration against depletion due to the radial drift and accelerates dust growth locally. In this work (Paper II), we perform numerical simulations of coagulation instability taking into account effects of backreaction to gas and collisional fragmentation of dust grains. We find that the slowdown of the dust drift due to backreaction regulates dust concentration in the nonlinear growth phase of coagulation instability. The dust-to-gas surface density ratio increases from 10^{-3} up to $\sim 10^{-2}$. Each resulting dust ring tends to have mass of $\simeq 0.5M_{\oplus} - 1.5M_{\oplus}$ in our disk model. In contrast to Paper I, the dust surface density profile shows a local plateau structure at each dust ring. In spite of the regulation at the nonlinear growth, the efficient dust concentration reduces their collision velocity. As a result, dust grains can grow beyond the fragmentation barrier, and the dimensionless stopping time reaches unity as in Paper I. The necessary condition for the efficient dust growth is (1) weak turbulence of $\alpha < 1 \times 10^{-3}$ and (2) a large critical velocity for dust fragmentation (> 1 m/s). The efficient dust concentration in outer regions will reduce the inward pebble flux and is expected to decelerate the planet formation via the pebble accretion. We also find that the resulting rings can be unstable to secular gravitational instability (GI). The subsequent secular GI promotes planetesimal formation. We thus expect that a combination of these instabilities is a promising mechanism for dust-ring and planetesimal formation.

48. Time-Variable Jet Ejections from RW Aur A, RY Tau and DG Tau

Michihiro Takami, Hans Moritz Guenther, P. Christian Schneider, Tracy L. Beck, Jennifer L. Karr, Youichi Ohyama, Roberto Galvan-Madrid, Taichi Uyama, Marc White, Konstantin Grankin, Deirdre Coffey, Chun-Fan Liu, Misato Fukagawa, Nadine Manset, Wen-Ping Chen, Tae-Soo Pyo, Hsien Shang, Thomas P. Ray, Masaaki Otsuka, Mei-Yin Chou ★ We present Gemini-NIFS, VLT-SINFONI and Keck-OSIRIS observations of near-infrared [Fe II] emission associated with the well-studied jets from three active T Tauri stars; RW Aur A, RY Tau and DG Tau taken from 2012-2021. We primarily covered the redshifted jet from RW Aur A, and the blueshifted jets from RY Tau and DG Tau, to investigate long-term time variabilities potentially related to the activities of mass accretion and/or the stellar magnetic fields. All of these jets consist of several moving knots with tangential velocities of 70-240 km s-1, ejected from the star with different velocities and at irregular time intervals. Via comparison with literature, we identify significant differences in tangential velocities for the DG Tau jet between 1985-2008 and 2008-2021. The sizes of the individual knots appear to increase with time, and in turn, their peak brightnesses in the 1.644-micron emission decreased up to a factor of 30 during the epochs of our observations. A variety of the decay timescales measured in the [Fe II] 1.644 micron emission can be attributed to different pre-shock conditions if the moving knots are unresolved shocks. However, our data do not exclude the possibility that these knots are due to non-uniform density/temperature distributions with another heating mechanism, or in some cases due to stationary shocks without proper motions. Spatially resolved observations of these knots with significantly higher angular resolutions are necessary to better understand their physical nature.

49. Mid-Infrared Polarization of the Diffuse Interstellar Medium toward CygOB2-12

Charles M. Telesco, Frank Varosi, Christopher Wright, Bruce T. Draine, Sergio Jose Fernández Acosta, Christopher Packham ★ We present the first mid-IR detection of the linear polarization toward the star CygOB2-12, a luminous blue hypergiant that, with AV of 10 mag of foreground extinction, is a benchmark in the study of the properties of dust in the diffuse interstellar medium. The 8-13 micrometer spectropolarimetry, obtained with the CanariCam multi-mode camera at the Gran Telescopio Canarias (GTC), shows clear trends with wavelength characteristic of silicate grains aligned in the interstellar magnetic field. The maximum polarization, detected with 7.8 statistical significance near 10.2 micrometers, is (1.24 +/- 0.28)% with position angle (126 +/- 8) deg. We comment on these measurements in the context of recent models for the dust composition in the diffuse interstellar medium.

50. Ionisation of inner T Tauri star discs: effects of in-situ energetic particles produced by strong magnetic reconnection events

Brunn V, Marcowith A, Sauty C, Padovani M, Rab C, Meskini C ★ Magnetic reconnection is one of the major particle acceleration processes in space and astrophysical plasmas. Low-energy supra-thermal particles emitted by magnetic reconnection are a source of ionisation for circumstellar discs, influencing their chemical, thermal and dynamical evolution. The aim of this work is to propose a first investigation to evaluate how energetic particles can propagate in the circumstellar disc of a T Tauri star and how they affect the ionisation rate of the disc plasma. To that end, we have collected experimental and theoretical cross sections for the production of H^+, H_2^+ and He^+ by electrons and protons. Starting from theoretical injection spectra of protons and electrons emitted during magnetic reconnection events, we have calculated the propagated spectra in the circumstellar disc considering the relevant energy loss processes. We have considered fluxes of energetic particles with different spectral indices and different disc magnetic configurations, generated at different positions from the star considering the physical properties of the flares as deduced from the observations obtained by the Chandra Orion Ultra Deep point source catalogue. We have then computed the ionisation rates for a disc whose structure has been calculated with the radiation thermo-chemical code `ProDiMo`. We find that energetic particles are potentially a very strong source of local ionisation with ionisation rates exceeding by several orders of magnitude the contribution due to X-rays, stellar energetic particles and radioactivity in the inner disc.

51. Residual Neural Networks for the Prediction of Planetary Collision Outcomes

Philip M. Winter, Christoph Burger, Sebastian Lehner, Johannes Kofler, Thomas I. Maindl, Christoph M. Schäfer ★ Fast and accurate treatment of collisions in the context of modern N-body planet formation simulations remains a challenging task due to inherently complex collision processes. We aim to tackle this problem with machine learning (ML), in particular via residual neural networks. Our model is motivated by the underlying physical processes of the data-generating process and allows for flexible prediction of post-collision states. We demonstrate that our model outperforms commonly used collision handling methods such as perfect inelastic merging and feed-forward neural networks in both prediction accuracy and out-of-distribution generalization. Our model outperforms the current state of the art in 20/24 experiments. We provide a dataset that consists of 10164 Smooth Particle Hydrodynamics (SPH) simulations of pairwise planetary collisions. The dataset is specifically suited for ML research to improve computational aspects for collision treatment and for studying planetary collisions in general. We formulate the ML task as a multi-task regression problem, allowing simple, yet efficient training of ML models for collision treatment in an end-to-end manner. Our models can be easily integrated into existing N-body frameworks and can be used within our chosen parameter space of initial conditions, i.e. where similar-sized collisions during late-stage terrestrial planet formation typically occur.

52. The interplay between forming planets and photo-evaporating discs I: Forbidden line diagnostics

Michael L. Weber, Barbara Ercolano, Giovanni Picogna, Christian Rab ★ Disc winds and planet formation are considered to be two of the most important mechanisms that drive the evolution and dispersal of protoplanetary discs and in turn define the environment in which planets form and evolve. While both have been studied extensively in the past, we combine them into one model by performing three-dimensional radiation-hydrodynamic simulations of giant planet hosting discs that are undergoing X-ray photo-evaporation, with the goal to analyse the interactions between both mechanisms. In order to study the effect on observational diagnostics, we produce synthetic observations of commonly used wind-tracing forbidden emission lines with detailed radiative transfer and photo-ionisation calculations. We find that a sufficiently massive giant planet carves a gap in the gas disc that is deep enough to affect the structure and kinematics of the pressure-driven photo-evaporative wind significantly. This effect can be strong enough to be visible in the synthetic high-resolution observations of some of our wind diagnostic lines, such as the [OI] 6300 A or [SII] 6730 A lines. When the disc is observed at inclinations around 40 deg and higher, the spectral line profiles may exhibit a peak in the redshifted part of the spectrum, which cannot easily be explained by simple wind models alone. Moreover, massive planets can induce asymmetric substructures within the disc and the photo-evaporative wind, giving rise to temporal variations of the line profiles that can be strong enough to be observable on timescales of less than a quarter of the planet's orbital period.

53. Discovery of non-metastable ammonia masers in Sagittarius B2

Y. T. Yan, C. Henkel, K. M. Menten, Y. Gong, H. Nguyen, J. Ott, A. Ginsburg, T. L. Wilson, A. Brunthaler, A. Belloche, J. S. Zhang, N. Budaiev, D. Jeff ★ We report the discovery of widespread maser emission in non-metastable inversion transitions of NH_3 toward various parts of the Sagittarius B2 molecular cloud/star forming region complex: We detect masers in the J, K = (6,3), (7,4), (8,5), (9,6), and (10,7) transitions toward Sgr B2(M) and Sgr B2(N), an NH_3 (6,3) maser in Sgr B2(NS), and NH_3 (7,4), (9,6), and (10,7) masers in Sgr B2(S). With the high angular resolution data of the Karl G. Jansky

Very Large Array (JVLA) in A-configuration we identify 18 maser spots. Nine maser spots arise from Sgr B2(N), one from Sgr B2(NS), five from Sgr B2(M), and three in Sgr B2(S). Compared to our Effelsberg single dish data, the JVLA data indicate no missing flux. The detected maser spots are not resolved by our JVLA observations. Lower limits to the brightness temperature are >3000 K and reach up to several 10^5 K, manifesting the lines' maser nature. In view of the masers' velocity differences with respect to adjacent hot molecular cores and/or UCHII regions, it is argued that all the measured ammonia maser lines may be associated with shocks caused either by outflows or by the expansion of UCHII regions. Overall, Sgr B2 is unique in that it allows us to measure many NH_3 masers simultaneously, which may be essential to elucidate their so far poorly understood origin and excitation.

54. Mass function of a young cluster in a low-metallicity environment. Sh 2-209

Chikako Yasui, Naoto Kobayashi, Masao Saito, Natsuko Izumi, Yuji Ikeda ★ We present deep near-infrared (NIR) imaging of Sh 2-209 (S209), a low-metallicity ([O/H] = -0.5 dex) HII region in the Galaxy. From the NIR images, combined with astrometric data from Gaia EDR3, we estimate the distance to S209 to be 2.5 kpc. This is close enough to enable us to resolve cluster members clearly ($\simeq$1000 AU separation) down to a mass-detection limit of $\simeq 0.1\ M_\odot$, and we have identified two star-forming clusters in S209, with individual cluster scales $\sim$1 pc. We employ a set of model luminosity functions to derive the underlying initial mass functions (IMFs) and ages for both clusters. The IMFs we obtained for both clusters exhibit slightly flat high-mass slopes ($\Gamma \simeq -1.0$) compared to the Salpeter IMF ($\Gamma = -1.35$), and their break mass of $\simeq 0.1\ M_\odot$ is lower than those generally seen in the solar neighborhood ($\sim 0.3\ M_\odot$). In particular, because the S209 main cluster is a star-forming cluster with a larger number of members ($\sim$1500) than the number ($\sim$100) in regions previously studied in such environments, it is possible for the first time to derive the IMF in a low-metallicity environment with high accuracy over the wide mass range 0.1–20 $M_\odot$.

55. Dust extinction map of the Galactic plane based on the VVV survey data

Miaomiao Zhang, Jouni Kainulainen ★ Dust extinction is one of the most reliable tracers of the gas distribution in the Milky Way. The near-infrared (NIR) Vista Variables in the Via Lactea (VVV) survey enables extinction mapping based on stellar photometry over a large area in the Galactic plane. We devise a novel extinction mapping approach, XPNICER, by bringing together VVV photometric catalogs, stellar parameter data from StarHorse catalogs, and previously published Xpercentile and PNICER extinction mapping techniques. We apply the approach to the VVV survey area, resulting in an extinction map that covers the Galactic disk between 295 and 350 degrees at longitude and -2 to 2 degrees at latitude, and the Galactic bulge between -10 and 5 degrees at latitude. The map has 30 arcseconds spatial resolution and it traces extinctions typically up to about 10-20 mag of visual extinction and maximally up to Av 30 mag. We compare our map to previous dust based maps, concluding that it provides a high-fidelity extinction-based map, especially in its ability to recover both the diffuse dust component of the Galaxy and moderately extincted giant molecular cloud regions. The map is especially useful as independent, extinction-based data on the Galactic dust distribution and applicable for a wide range of studies from individual molecular clouds to the studies of the Galactic stellar populations.

56. Turbulent Transport of Dust Particles in Protostellar Disks: The Effect of Upstream Diffusion

Ting-Tao Zhou, Hongping Deng, Yi-Xian Chen, Douglas N. C. Lin ★ We study the long-term radial transport of micron to mm-size grain in protostellar disks (PSDs) based on diffusion and viscosity coefficients measured from 3D global stratified-disk simulations with a Lagrangian hydrodynamic method. While gas-drag tend to transport dust species radially inwards, stochastic diffusion can spread a considerable fraction of dust radially outwards (upstream) depending on the nature of turbulence. In gravitationally unstable disks, we measure a high radial diffusion coefficient Dr with little dependence on altitude. This leads to strong and vertically homogeneous upstream diffusion in early PSDs. In the solar nebula, the robust upstream diffusion of micron to mm size grains not only efficiently transports highly refractory mocron-size grains (such as those identified in the samples of comet 81P/Wild 2) from their regions of formation inside the snow line out to the Kuiper Belt, but can also spread mm-size CAI formed in the stellar proximity to distances where they can be assimilated into chondritic meteorites. In disks dominated by magnetorotational instability (MRI), the upstream diffusion effect is generally milder, with a separating feature due to diffusion being stronger in the surface layer than the midplane. This variation becomes much more pronounced if we additionally consider a quiescent midplane with lower turbulence and larger characteristic dust size due to non-ideal MHD effects. This segregation scenario helps to account for dichotomy of two dust populations' spatial distribution as observed in scattered light and ALMA images.