The Star Formation Newsletter

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Links to sections

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

Cover image caption

The Pleiades star cluster. The cover of SFN 338 is dedicated to John Stauffer who passed away on January 29, 2021. John was a leading stellar astronomer, a wonderful colleague, and the leading Pleiades explorer. John loved the Pleiades. Almost half of John's refereed papers, or 176 to be precise, mention this benchmark stellar cluster. Read more about John's stellar career in the **Obituary** written by Lee Hartmann and David Barrado Navascués (John's photo courtesy of Linda Stauffer). Credits: Digitized Sky Survey, NASA/ESA/AURA/Caltech.

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. We extract the title, authors, and the abstract's text directly from the arXiv, so make sure not to remove the LaTeX formatting when submitting to the arXiv. If you do, your abstract will not look great either at the arXiv (which uses MathJax to convert LaTeX math symbols to the web) or the SFN.

Abstracts

1. ## A Theoretical Framework for the Mass Distribution of Gas Giant Planets forming through the Core Accretion Paradigm

Fred C Adams, Michael R Meyer, Arthur D Adams ★ This paper constructs a theoretical framework for calculating the distribution of masses for gas giant planets forming via the core accretion paradigm. Starting with known properties of circumstellar disks, we present models for the planetary mass distribution over the range $0.1 M_J < M_{\rm p} < 10 M_J$. If the circumstellar disk lifetime is solely responsible for the end of planetary mass accretion, the observed (nearly) exponential distribution of disk lifetime would imprint an exponential fall-off in the planetary mass function. This result is in apparent conflict with observations, which suggest that the mass distribution has a (nearly) power-law form $dF/dM_{\rm p} \sim M_{\rm p}^{-p}$, with index $p \approx 1.3$, over the relevant planetary mass range (and for stellar masses $\sim 0.5 - 2 M_\odot$). The mass accretion rate onto the planet depends on the fraction of the (circumstellar) disk accretion flow that enters the Hill sphere, and on the efficiency with which the planet captures the incoming material. Models for the planetary mass function that include distributions for these efficiencies, with uninformed priors, can produce nearly power-law behavior, consistent with current observations. The disk lifetimes, accretion rates, and other input parameters depend on the mass of the host star. We show how these variations lead to different forms for the planetary mass function for different stellar masses. Compared to stars with masses $M_* = 0.5 - 2 M_\odot$, stars with smaller masses are predicted to have a steeper planetary mass function (fewer large planets).

2. ## Particle Dynamics in 3D Self-gravitating Disks I: Spirals

Hans Baehr, Zhaohuan Zhu ★ Spiral arms are distinctive features of many circumstellar disks, observed in scattered light, which traces the disk surface, millimeter dust emission, which probes the disk midplane, as well as molecular emission. The two leading explanations for spirals are wakes generated by a massive planet and the density waves excited by disk self-gravity. We use stratified 3D hydrodynamic shearing-box simulations including dust particles and disk self-gravity to investigate how gas and dust spirals in a self-gravitating disk depend on the simulation size, the cooling efficiency, and the aerodynamics properties of particles. We find that opening angles of spirals are universal ($\sim 10^o$), and not significantly affected by the size of the computational domain, the cooling time, or the particle size. In simulations with the biggest domain, the spirals in the gaseous disk become slightly more open with a higher cooling efficiency. Small dust follows the gaseous spirals very well, while intermediate-sized dust with dimensionless stopping time (St) close to 1 concentrates to the spirals more and shows stronger spirals. However, large dust with St > 1 also shows spirals, which is different from some previous simulations. We identify that this is due to the gravity from the gas to the dust component. We show that when St $\gtrsim Q$, the gravitational force from the gaseous spirals to the dust particles becomes stronger than the particles' aerodynamic drag force, so that the gas significantly

affects these large particles through gravitational interaction. This has important implications for both spiral observations and planetesimal formation/dynamics.

3. Particle Dynamics in 3D Self-gravitating Disks II: Strong Gas Accretion and Thin Dust Disks

Hans Baehr, Zhaohuan Zhu ★ Observations suggest that protoplanetary disks have moderate accretion rates onto the central young star, especially at early stages (e.g. HL Tau), indicating moderate disk turbulence. However, recent ALMA observations suggest that dust is highly settled, implying weak turbulence. Motivated by such tension, we carry out 3D stratified local simulations of self-gravitating disks, focusing on settling of dust particles in actively accreting disks. We find that gravitationally unstable disks can have moderately high accretion rates while maintaining a relatively thin dust disk for two reasons. First, accretion stress from the self-gravitating spirals (self-gravity stress) can be stronger than the stress from turbulence (Reynolds stress) by a factor of 5-20. Second, the strong gravity from the gas to the dust decreases the dust scale height by another factor of ~ 2. Furthermore, the turbulence is slightly anisotropic, producing a larger Reynolds stress than the vertical dust diffusion coefficient. Thus, gravitoturbulent disks have unusually high vertical Schmidt numbers (Sc_z) if we scale the total accretion stress with the vertical diffusion coefficient (e.g. $Sc_z \sim$ 10-100). The reduction of the dust scale height by the gas gravity, should also operate in gravitationally stable disks ($Q >$1). Gravitational forces between particles become more relevant for the concentration of intermediate dust sizes, forming dense clouds of dust. After comparing with HL Tau observations, our results suggest that self-gravity and gravity among different disk components could be crucial for solving the conflict between the protoplanetary disk accretion and dust settling, at least at the early stages.

4. A possible far-ultraviolet flux-dependent core mass function in NGC 6357

J. Brand, A. Giannetti, F. Massi, J. G. A. Wouterloot, C. Verdirame ★ To derive the properties of the dense cores in the galactic star-forming complex NGC6357 and to investigate the effects of an intense far-UV radiation field on their properties, we mapped the region at 450 and 850 micron, and in the CO(3-2) line with the JCMT. We also made use of the Herschel Hi-GAL data at 70 and 160 micron. We used Gaussclumps to retrieve 686 compact cores embedded in the diffuse sub-mm emission and constructed their SED from 70 to 850 micron, from which we derived mass and temperature. The estimated mass completeness limit is 5Mo. We divided the observed area in an 'active' region, exposed to the far-UV radiation from the more massive members of three star clusters (411 cores), and a 'quiescent' region, less affected by far-UV radiation (275 cores). We also attempted to select a sample of pre-stellar cores based on cross-correlation with 70 micron emission and red WISE point sources. Most of the cores above the mass completeness limit are likely to be gravitationally bound. The fraction of gas in dense cores is very low, 1.4mass-size relation log(M/Mo) (2.0-2.4) x log (D/arcsec), depending on the precise selection of the sample. The temperature distributions in the two sub-regions are clearly different, peaking at 25K in the quiescent region and at 35K in the active region. The core mass functions are different as well, at a 2sigma level, consistent with a Salpeter IMF in the quiescent region and flatter than that in the active region. The dense cores lying close to the HII regions are consistent with pre-existing cores being gradually engulfed by a PDR and photoevaporating. We attribute the different global properties of dense cores in the two sub-regions to the influence of the far-UV radiation field.

5. Tracers of the ionization fraction in dense and translucent gas: I. Automated exploitation of massive astrochemical model grids

Emeric Bron, Evelyne Roueff, Maryvonne Gerin, Jérôme Pety, Pierre Gratier, Franck Le Petit, Viviana Guzman, Jan H. Orkisz, Victor de Souza Magalhaes, Mathilde Gaudel, Maxime Vono, Sébastien Bardeau, Pierre Chainais, Javier R. Goicoechea, Annie Hughes, Jouni Kainulainen, David Languignon, Jacques Le Bourlot, François Levrier, Harvey Liszt, Karin Öberg, Nicolas Peretto, Antoine Roueff, Albrecht Sievers ★ The ionization fraction plays a key role in the physics and chemistry of the neutral interstellar medium, from controlling the coupling of the gas to the magnetic field to allowing fast ion-neutral reactions that drive interstellar chemistry. Most estimations of the ionization fraction have relied on deuterated species such as DCO+, whose detection is limited to dense cores representing an extremely small fraction of the volume of the giant molecular clouds they are part of. As large field-of-view hyperspectral maps become available, new tracers may be found. We search for the best observable tracers of the ionization fraction based on a grid of astrochemical models. We build grids of models that sample randomly a large space of physical conditions (unobservable quantities such as gas density, temperature, etc.) and compute the corresponding observables (line intensities, column densities) and the ionization fraction. We estimate the predictive power of each potential tracer by training a Random Forest model to predict the ionization fraction from that tracer, based on these model grids. In both translucent medium and cold dense medium conditions, several observable tracers with very good predictive power for the ionization fraction are found. Several tracers in cold dense medium conditions are found to be better and more widely applicable than the traditional DCO+/HCO+ ratio. We also provide simpler analytical fits for estimating the ionization fraction from the best tracers, and for estimating the associated uncertainties. We discuss the limitations of the present study and select a few recommended tracers in both types of conditions. The method presented here is very general and can be applied to the measurement of any other quantity of interest

(cosmic ray flux, elemental abundances, etc.) from any type of model (PDR models, time-dependent chemical models, etc.). (abridged)

6. Radial Velocity Monitoring of the Young Star Hubble 4: Disentangling Starspot Lifetimes from Orbital Motion

Adolfo Carvalho, Christopher M. Johns-Krull, L. Prato, Jay Anderson ★ We studied the weak-lined T Tauri star Hubble 4, a known long-period binary, and its starspot phenomena. We used optical radial velocity (RV) data taken over a span of 14 years (2004-2010, 2017-2019) at the McDonald Observatory 2.7m Harlan J. Smith telescope and single epoch imaging from the HST/WFC3 instrument. The observed and apparent RV variations show contributions, respectively, from the binary motion as well as from a large spot group on one of the stars, presumed to be the primary. Fitting and removing the orbital signal from the RVs, we found the lower bound on the lifetime of a previously identified large spot group on the surface of the star to be at least 5.1 years. A ~ 5 year lower limit is a long, but not unprecedented, duration for a single spot group. The later epoch data indicate significant spot evolution has occurred, placing an upper bound on the spot group lifetime at 12 years. We find that pre-main sequence evolutionary models for the age of Taurus (~ 2 Myr), combined with component mass estimates from the literature, permit us to reproduce the HST relative photometry and the binary-induced contribution to the apparent RV variations. The long-lived star spot we find on Hubble 4 has significant implications for dynamo models in young stars, as it adds evidence for long lifetimes of magnetic field topologies. There are also significant implications for young star exoplanet searches as long-lived coherent RV signals may be spot-induced and not the result of planetary motion. (This paper includes data taken at The McDonald Observatory of The University of Texas at Austin.)

7. The Extraordinary Outburst in the Massive Protostellar System NGC6334I-MM1: Spatio-kinematics of Water Masers during a Contemporaneous Flare Event

James O. Chibueze, Gordon C. Macleod, Jakobus M. Vorster, Tomoya Hirota, Crystal L. Brogan, Todd R. Hunter, Ruby Van Rooyen ★ Following an eruptive accretion event in NGC6334I-MM1, flares in the various maser species, including water masers, were triggered. We report the observed relative proper motion of the highly variable water masers associated with the massive star-forming region, NGC6334I. High velocity H_2O maser proper motions were detected in 5 maser clusters, CM2-W2 (bow-shock structure), MM1-W1, MM1-W3, UCHII-W1 and UCHII-W3. The overall average of the derived relative proper motion is 85 km s^{-1}. This mean proper motion is in agreement with the previous results from VLA multi-epoch observations. Our position and velocity variance and co-variance matrix analyses of the maser proper motions show its major axis to have a position angle of $-79.4°$, cutting through the dust cavity around MM1B and aligned in the northwest-southeast direction. We interpret this as the axis of the jet driving the CM2 shock and the maser motion. The complicated proper motions in MM1-W1 can be explained by the combined influence of the MM1 northeast-southwest bipolar outflow, CS(6-5) north-south collimated bipolar outflow, and the radio jet. The relative proper motions of the H_2O masers in UCHII-W1 are likely not driven by the jets of MM1B protostar but by MM3-UCHII. Overall, the post-accretion burst relative proper motions of the H_2O masers trace shocks of jet motion.

8. The GRAVITY young stellar object survey V. The orbit of the T Tauri binary star WW Cha

GRAVITY Collaboration, F. Eupen et al. ★ The young T Tauri star WW Cha was recently proposed to be a close binary object with strong infrared and submillimeter excess associated with circum-system emission. This makes WW Cha a very interesting source for studying the influence of dynamical effects on circumstellar as well as circumbinary material. We derive the relative astrometric positions and flux ratios of the stellar companion in WW Cha from the interferometric model fitting of observations made with the VLTI instruments AMBER, PIONIER, and GRAVITY in the near-infrared from 2011 to 2020. For two epochs, the resulting uv-coverage in spatial frequencies permits us to perform the first image reconstruction of the system in the K band. The positions of nine epochs are used to determine the orbital elements and the total mass of the system. We find the secondary star orbiting the primary with a period of T=206.55 days, a semimajor axis of a=1.01 au, and a relatively high eccentricity of e=0.45. Combining the orbital solution with distance measurements from Gaia DR2 and the analysis of evolutionary tracks, the dynamical mass of Mtot=3.20 Msol can be explained by a mass ratio between 0.5 and 1. The orbital angular momentum vector is in close alignment with the angular momentum vector of the outer disk as measured by ALMA and SPHERE. The analysis of the relative photometry suggests the presence of infrared excess surviving in the system and likely originating from truncated circumstellar disks. The flux ratio between the two components appears variable, in particular in the K band, and may hint at periods of triggered higher and lower accretion or changes in the disks' structures. The knowledge of the orbital parameters, combined with a relatively short period, makes WW Cha an ideal target for studying the interaction of a close young T Tauri binary with its surrounding material, such as time-dependent accretion phenomena.

9. Testing the role of environmental effects on the Initial Mass Function of low mass stars

Belinda Damian, Jessy Jose, Manash R. Samal, Estelle Moraux, Swagat R. Das, Sudeshna Patra ★ In star formation process, the vital role of environmental factors such as feedback from massive stars and stellar density on the form of the Initial Mass Function (IMF) at low-mass end is yet to be understood. Hence a systematic, high sensitive observational analysis of a sample of regions under diverse environmental conditions is essential. We analyse the IMF of eight young clusters (<5 Myr) namely IC1848-West, IC1848-East, NGC1893, NGC2244, NGC2362, NGC6611, Stock8 and Cygnus OB2 which are located at the Galactocentric distance (R_g) range ∼6-12 kpc along with nearby cluster IC348 using deep near-IR photometry and Gaia-DR2. These clusters are embedded in massive stellar environments of radiation strength $log(L_{FUV}/L_{\odot})$ ∼2.6 to 6.8, $log(L_{EUV})$ ∼42.2 to 50.85 photons/s, with stellar density in the range of ∼170 - 1220 stars/pc^2. After structural analysis and field decontamination we obtain an unbiased, uniformly sensitive sample of Pre-Main Sequence members of the clusters down to brown-dwarf regime. The log-normal fit to the IMF of nine clusters gives the mean characteristic mass (m_c) and σ of 0.32±0.02 $M_{\odot}$ and 0.47±0.02, respectively. We compare the IMF with that of low and high mass clusters across the Milky Way. We also check for any systematic variation with respect to the radiation field strength, stellar density as well with R_g. We conclude that there is no strong evidence for environmental effect in the underlying form of IMF of these clusters.

10. The properties of clusters, and the orientation of magnetic fields relative to filaments, in magnetohydrodynamic simulations of colliding clouds

C. L. Dobbs, J. Wurster ★ We have performed Smoothed Particle Magneto-Hydrodynamics (SPMHD) calculations of colliding clouds to investigate the formation of massive stellar clusters, adopting a timestep criterion to prevent large divergence errors. We find that magnetic fields do not impede the formation of young massive clusters (YMCs), and the development of high star formation rates, although we do see a strong dependence of our results on the direction of the magnetic field. If the field is initially perpendicular to the collision, and sufficiently strong, we find that star formation is delayed, and the morphology of the resulting clusters is significantly altered. We relate this to the large amplification of the field with this initial orientation. We also see that filaments formed with this configuration are less dense. When the field is parallel to the collision, there is much less amplification of the field, dense filaments form, and the formation of clusters is similar to the purely hydrodynamical case. Our simulations reproduce the observed tendency for magnetic fields to be aligned perpendicularly to dense filaments, and parallel to low density filaments. Overall our results are in broad agreement with past work in this area using grid codes.

11. Quantitative inference of the H_2 column densities from 3 mm molecular emission: A case study towards Orion B

Pierre Gratier, Jérôme Pety, Emeric Bron, Antoine Roueff, Jan H. Orkisz, Maryvonne Gerin, Victor de Souza Magalhaes, Mathilde Gaudel, Maxime Vono, Sébastien Bardeau, Jocelyn Chanussot, Pierre Chainais, Javier R. Goicoechea, Viviana V. Guzmán, Annie Hughes, Jouni Kainulainen, David Languignon, Jacques Le Bourlot, Franck Le Petit, François Levrier, Harvey Liszt, Nicolas Peretto, Evelyne Roueff, Albrecht Sievers ★ Molecular hydrogen being unobservable in cold molecular clouds, the column density measurements of molecular gas currently rely either on dust emission observation in the far-IR or on star counting. (Sub-)millimeter observations of numerous trace molecules are effective from ground based telescopes, but the relationships between the emission of one molecular line and the H2 column density (NH2) is non-linear and sensitive to excitation conditions, optical depths, abundance variations due to the underlying physico-chemistry. We aim to use multi-molecule line emission to infer NH2 from radio observations. We propose a data-driven approach to determine NH2 from radio molecular line observations. We use supervised machine learning methods (Random Forests) on wide-field hyperspectral IRAM-30m observations of the Orion B molecular cloud to train a predictor of NH2, using a limited set of molecular lines as input, and the Herschel-based dust-derived NH2 as ground truth output. For conditions similar to the Orion B molecular cloud, we obtain predictions of NH2 within a typical factor of 1.2 from the Herschel-based estimates. An analysis of the contributions of the different lines to the predictions show that the most important lines are ^{13}CO(1-0), ^{12}CO(1-0), C^{18}O(1-0), and HCO$^+$(1-0). A detailed analysis distinguishing between diffuse, translucent, filamentary, and dense core conditions show that the importance of these four lines depends on the regime, and that it is recommended to add the N_2H^+(1-0) and CH_3OH(20-10) lines for the prediction of NH2 in dense core conditions. This article opens a promising avenue to directly infer important physical parameters from the molecular line emission in the millimeter domain. The next step will be to try to infer several parameters simultaneously (e.g., NH2 and far-UV illumination field) to further test the method. [Abridged]

12. Density profile evolution during prestellar core collapse: Collapse starts at the large scale

Gilberto C. Gómez, Enrique Vázquez-Semadeni, Aina Palau ★ We study the gravitationally-dominated, accretion-driven evolution of a prestellar core. In our model, as the core's density increases, it remains immersed in a constant-density environment and so it accretes from this environment, increasing its mass and reducing its Jeans length. Assuming a power-law density profile $\rho \propto r^{-p}$, we compute the rate of change of the slope p, and show that the value $p = 2$ is stationary, and

furthermore, an attractor. The radial profile of the Jeans length scales as $r^{p/2}$, implying that, for $p < 2$, there is a radius below which the region is smaller than its Jeans length, thus appearing gravitationally stable and in need of pressure confinement, while, in reality, it is part of a larger-scale collapse and is undergoing compression by the infalling material. In this region, the infall speed decreases towards the center, eventually becoming subsonic, thus appearing "coherent", without the need for turbulence dissipation. We present a compilation of observational determinations of density profiles in dense cores and show that the distribution of their slopes peaks at $p \sim 1.7$–1.9, supporting the notion that the profile steepens over time. Finally, we discuss the case of magnetic support in a core in which the field scales as $B \propto \rho^{\beta}$. For the expected value of $\beta = 2/3$, this implies that the mass to magnetic flux ratio also decreases towards the central parts of the cores, making them appear magnetically supported, while in reality they may be part of larger collapsing supercritical region. We conclude that local signatures of either thermal or magnetic support are not conclusive evidence of stability, that the gravitational instability of a region must be established at the large scales, and that the prestellar stage of collapse is dynamic rather than quasistatic.

13. Resolved molecular line observations reveal an inherited molecular layer in the young disk around TMC1A

Daniel Harsono, Matthijs van der Wiel, Per Bjerkeli, Jon Ramsey, Hannah Calcutt, Lars Kristensen, Jes Jørgensen ★ Physical processes that govern the star and planet formation sequence influence the chemical composition and evolution of protoplanetary disks. To understand the chemical composition of protoplanets, we need to constrain the composition and structure of the disks from whence they are formed. We aim to determine the molecular abundance structure of the young disk around the TMC1A protostar on au scales in order to understand its chemical structure and any possible implications for disk formation. We present spatially resolved Atacama Large Millimeter/submillimeter Array observations of CO, HCO^+, HCN, DCN, and SO line emission, as well as dust continuum emission, in the vicinity of TMC1A. Molecular column densities are estimated both under the assumption of optically thin emission from molecules in LTE as well as through more detailed non-LTE radiative transfer calculations. Resolved dust continuum emission from the disk is detected between 220 and 260 GHz. Rotational transitions from HCO^+, HCN, and SO are also detected from the inner 100 au region. From the derived HCO^+ abundance, we estimate the ionization fraction of the disk surface and find values that imply that the accretion process is not driven by the magneto-rotational instability. The molecular abundances averaged over the TMC1A disk are similar to its protostellar envelope and other, older Class II disks. We meanwhile find a discrepancy between the young disk's molecular abundances relative to Solar System objects. Abundance comparisons between the disk and its surrounding envelope for several molecular species reveal that the bulk of planet-forming material enters the disk unaltered. Differences in HCN and H_2O molecular abundances between the disk around TMC1A, Class II disks, and Solar System objects trace the chemical evolution during disk and planet formation.

14. Outbursting Young Stellar Object PGIR 20dci in the Perseus Arm

Lynne A. Hillenbrand, Kishalay De, Matthew Hankins, Mansi M. Kasliwal, Luisa M. Rebull, Ryan M. Lau, Roc M. Cutri, Michael C. B. Ashley, Viraj R. Karambelkar, Anna M. Moore, T. Travouillon, A. K. Mainzer ★ We report the discovery of a likely outbursting Class I young stellar object, associated with the star-forming region NGC 281-W (distance $\sim$ 2.8 kpc). The source is currently seen only at infrared wavelengths, appearing in both the Palomar Gattini InfraRed (1.2 μm) and the Near Earth Object Widefield Infrared Survey Explorer (3.4 and 4.6 μm) photometric time-domain surveys. Recent near-infrared imaging reveals a new, extended scattered light nebula. Recent near-infrared spectroscopy confirms the similarity of PGIR 20dci to FU Ori type sources, based on strong molecular absorption in CO, H_2O, and OH, weak absorption in several atomic lines, and a warm wind/outflow as indicated by a P Cygni profile in the HeI 10830 A line. This is a rare case of an FU Ori star with a well-measured long term photometric rise before a sharper outburst, and the second instance of an FU Ori star with a documented two-step brightening in the mid-infrared.

15. The β Pictoris b Hill sphere transit campaign. Paper I: Photometric limits to dust and rings

M. A. Kenworthy, S. N. Mellon, J. I. Bailey III, R. Stuik, P. Dorval, G. -J. J. Talens, S. R. Crawford, E. E. Mamajek, I. Laginja, M. Ireland, B. Lomberg, R. B. Kuhn, I. Snellen, K. Zwintz, R. Kuschnig, G. M. Kennedy, L. Abe, A. Agabi, D. Mekarnia, T. Guillot, F. Schmider, P. Stee, Y. de Pra, M. Buttu, N. Crouzet, P. Kalas, J. J. Wang, K. Stevenson, E. de Mooij, A. -M. Lagrange, S. Lacour, A. Lecavelier des Etangs, M. Nowak, P. A. Strøm, Z. Hui, L. Wang ★ Photometric monitoring of Beta Pictoris in 1981 showed anomalous fluctuations of up to 4the stellar disk. The subsequent discovery of the gas giant planet Beta Pictoris b and the predicted transit of its Hill sphere to within 0.1 au projected distance of the planet provided an opportunity to search for the transit of a circumplanetary disk in this 21 ± 4 Myr-old planetary system. Continuous broadband photometric monitoring of Beta Pictoris requires ground-based observatories at multiple longitudes to provide redundancy and to provide triggers for rapid spectroscopic followup. These observatories include the dedicated Beta Pictoris monitoring observatory bRing at Sutherland and Siding Springs, the ASTEP400 telescope at Concordia, and observations from the space observatories BRITE and Hubble Space Telescope. We search the combined light

curves for evidence of short period transient events caused by rings and for longer term photometric variability due to diffuse circumplanetary material. We find no photometric event that matches with the event seen in November 1981, and there is no systematic photometric dimming of the star as a function of the Hill sphere radius. We conclude that the 1981 event was not caused by the transit of a circumplanetary disk around Beta Pictoris b. The upper limit on the long term variability of Beta Pictoris places an upper limit of 1.8×10^{22} g of dust within the Hill sphere. Circumplanetary material is either condensed into a non-transiting disk, is condensed into a disk with moons that has a small obliquity, or is below our detection threshold. This is the first time that a dedicated international campaign has mapped the Hill sphere transit of a gas giant extrasolar planet at 10 au.

16. The warm-up phase in massive star-forming cores around RCW 120

M. S. Kirsanova, S. V. Salii, S. V. Kalenskii, D. S. Wiebe, A. M. Sobolev, P. A. Boley ★ We study molecular emission in a massive condensation at the border of the HII region RCW 120, paying particular attention to the Core 1 and Core 2 objects, the most massive fragments of the condensation found previously by ALMA. The latter fragment was previously suggested to host a high-mass analogue of Class 0 young stellar object. We present spectra of molecular emission in the 1 mm range made with the APEX telescope. We detect CH_3OH and $C^{34}S$ lines in Core 1 and Core 2. The CH_3CN series and the SO_2 lines are only found in Core 2. We estimate gas physical parameters using methanol lines and obtain gas temperature less than 100 K in both regions. Molecular hydrogen number density in Core 2 is in the range of $10^5 - 10^7$ cm^{-3} and is more uncertain in Core 1. However, the detection of the CH_3CN lines corresponding to highly excited transitions ($E_u > 400$ K) in Core 2 indicates that the region contains hot gas, while the abundances of CH_3OH, CS, SO_2 and CH_3CN are quite low for a hot core stage. We propose that Core 2 is in the warm-up phase prior to the establishing of the hot gas chemistry. We suggest that Core 2 is in the beginning of the hot core stage. There are no detected CH_3CN lines in Core 1, therefore, it might be on an even less evolved evolutionary stage.

17. New low-mass members of Chamaeleon I and η Cha

K. Kubiak, K. Mužić, I. Sousa, V. Almendros-Abad, R. Köhler, A. Scholz ★ The goal of this paper is to increase the membership list of the Chamaeleon star forming region and the ϵ Cha moving group, in particular for low-mass stars and substellar objects. We extended the search region significantly beyond the dark clouds. Our sample has been selected based on proper motions and colours obtained from Gaia and 2MASS. We present and discuss the optical spectroscopic follow-up of 18 low-mass stellar objects in Cha I and ϵ Cha. We characterize the properties of objects by deriving their physical parameters, both from spectroscopy and photometry. We add three more low-mass members to the list of Cha I, and increase the census of known ϵ Cha members by more than 40members and relying on X-ray emission as youth indicator for 2 more. In most cases the best-fitting spectral template is from objects in the TW Hya association, indicating that ϵ Cha has a similar age. The first estimate of the slope of the initial mass function in ϵ Cha down to the sub-stellar regime is consistent with that of other young clusters. We estimate our IMF to be complete down to $\approx 0.03 M_\odot$. The IMF can be represented by two power laws: for $M < 0.5\ M_\odot$ $\alpha = 0.42 \pm 0.11$ and for $M > 0.5\ M_\odot$ $\alpha = 1.44 \pm 0.12$. We find similarities between ϵ Cha and the southernmost part of Lower Centaurus Crux (LCC A0), both lying at similar distances and sharing the same proper motions. This suggests that ϵ Cha and LCC A0 may have been born during the same star formation event

18. ALMA Observations of Massive Clouds in the Central Molecular Zone: Ubiquitous Protostellar Outflows

Xing Lu, Shanghuo Li, Adam Ginsburg, Steven N. Longmore, J. M. Diederik Kruijssen, Daniel L. Walker, Siyi Feng, Qizhou Zhang, Cara Battersby, Thushara Pillai, Elisabeth A. C. Mills, Jens Kauffmann, Yu Cheng, Shu-ichiro Inutsuka ★ We observe 1.3 mm spectral lines at 2000 AU resolution toward four massive molecular clouds in the Central Molecular Zone of the Galaxy to investigate their star formation activities. We focus on several potential shock tracers that are usually abundant in protostellar outflows, including SiO, SO, CH_3OH, H_2CO, HC_3N, and HNCO. We identify 43 protostellar outflows, including 37 highly likely ones and 6 candidates. The outflows are found toward both known high-mass star forming cores and less massive, seemingly quiescent cores, while 791 out of the 834 cores identified based on the continuum do not have detected outflows. The outflow masses range from less than 1 $M_\odot$ to a few tens of $M_\odot$, with typical uncertainties of a factor of 70. We do not find evidence of disagreement between relative molecular abundances in these outflows and in nearby analogs such as the well-studied L1157 and NGC7538S outflows. The results suggest that i) protostellar accretion disks driving outflows ubiquitously exist in the CMZ environment, ii) the large fraction of candidate starless cores is expected if these clouds are at very early evolutionary phases, with a caveat on the potential incompleteness of the outflows, iii) high-mass and low-mass star formation is ongoing simultaneously in these clouds, and iv) current data do not show evidence of difference between the shock chemistry in the outflows that determines the molecular abundances in the CMZ environment and in nearby clouds.

19. Characterizing the dust content of disk substructures in TW Hya

Enrique Macias, Osmar Guerra-Alvarado, Carlos Carrasco-Gonzalez, Alvaro Ribas, Catherine C. Espaillat, Jane Huang, Sean M. Andrews ★ We present Atacama Large Millimeter Array (ALMA) observations of TW Hya at 3.1 mm with $\sim$ 50 milliarcsecond resolution. These new data were combined with archival high angular resolution ALMA observations at 0.87 mm, 1.3 mm, and 2.1 mm. We analyze these multi-wavelength data to infer a disk radial profile of the dust surface density, maximum particle size, and slope of the particle size distribution. Most previously known annular substructures in the disk of TW Hya are resolved at the four wavelengths. Inside the inner 3 au cavity, the 2.1 mm and 3.1 mm images show a compact source of free-free emission, likely associated with an ionized jet. Our multi-wavelength analysis of the dust emission shows that the maximum particle size in the disk of TW Hya is $>$ 1 mm. The inner 20 au are completely optically thick at all four bands, which results in the data tracing different disk heights at different wavelengths. Coupled with the effects of dust settling, this prevents the derivation of accurate density and grain size estimates in these regions. At $r > 20$ au, we find evidence of the accumulation of large dust particle at the position of the bright rings, indicating that these are working as dust traps. The total dust mass in the disk is between 250 and 330 $M_{\oplus}$, which represents a gas-to-dust mass ratio between 50 and 70. Our mass measurement is a factor of 4.5-5.9 higher than the mass that one would estimate using the typical assumptions of large demographic surveys. Our results indicate that the ring substructures in TW Hya are ideal locations to trigger the streaming instability and form new generations of planetesimals.

20. Radiative scale-height and shadows in protoplanetary disks

Matías Montesinos, Nicolás Cuello, Johan Olofsson, Jorge Cuadra, Amelia Bayo, Gesa H. -M. Bertrang, Clément Perrot ★ Planets form in young circumstellar disks called protoplanetary disks. However, it is still difficult to catch planet formation in-situ. Nevertheless, from recent ALMA/SPHERE data, encouraging evidence of the direct and indirect presence of embedded planets has been identified in disks around young stars: co-moving point sources, gravitational perturbations, rings, cavities, and emission dips or shadows cast on disks. The interpretation of these observations needs a robust physical framework to deduce the complex disk geometry. In particular, protoplanetary disk models usually assume the gas pressure scale-height given by the ratio of the sound speed over the azimuthal velocity $H/r = c_s/v_{\rm k}$. By doing so, *radiative* pressure fields are often ignored, which could lead to a misinterpretation of the real vertical structure of such disks. We follow the evolution of a gaseous disk with an embedded Jupiter mass planet through hydrodynamical simulations, computing the disk scale-height including radiative pressure, which was derived from a generalization of the stellar atmosphere theory. We focus on the vertical impact of the radiative pressure in the vicinity of circumplanetary disks, where temperatures can reach $\gtrsim$ 1000 K for an accreting planet, and radiative forces can overcome gravitational forces from the planet. The radiation-pressure effects create a vertical optically thick column of gas and dust at the proto-planet location, casting a shadow in scattered light. This mechanism could explain the peculiar illumination patterns observed in some disks around young stars such as HD 169142 where a moving shadow has been detected, or the extremely high aspect-ratio $H/r \sim 0.2$ observed in systems like AB Aur and CT Cha.

21. Revealing a Centrally Condensed Structure in OMC-3/MMS 3 with ALMA High Resolution Observations

Kaho Morii, Satoko Takahashi, Masahiro N. Machida ★ Using the Atacama Large Millimeter/submillimeter Array (ALMA), we investigated a peculiar millimeter source MMS 3 located in the Orion Molecular Cloud 3 (OMC-3) region in the 1.3 mm continuum, CO (J=2-1), SiO (J=5-4), $C^{18}O$ (J=2-1), N_2D^+ (J=3-2), and DCN (J=3-2) emissions. With the ALMA high angular resolution ($\sim$0".2), we detected a very compact and highly centrally condensed continuum emission with a size of 0".45 $\times$ 0".32 (P.A.=0.22°). The peak position coincides with the locations of previously reported *Spitzer*/IRAC and X-ray sources within their positional uncertainties. We also detected an envelope with a diameter of $\sim$6800 au (P.A.=75°) in the $C^{18}O$ (J=2-1) emission. Moreover, a bipolar outflow was detected in the CO (J=2-1) emission for the first time. The outflow elongates roughly perpendicular to the long axis of the envelope detected in the $C^{18}O$ (J=2-1) emission. Compact high-velocity CO gas in the (red-shifted) velocity range of 22-30 km s^{-1}, presumably tracing a jet, was detected near the 1.3 mm continuum peak. A compact and faint red-shifted SiO emission was marginally detected on the CO outflow lobe. The physical quantities of the outflow in MMS 3 are relatively smaller than those in other sources in the OMC-3 region. The centrally condensed object associated with the near-infrared and X-ray sources, the flattened envelope, and the faint outflow indicate that MMS 3 harbors a low mass protostar with an age of $\sim 10^3$ yr.

22. Principal component analysis tomography in near-infrared integral field spectroscopy of young stellar objects. I. Revisiting the high-mass protostar W33A

Felipe Navarete, Augusto Damineli, João E. Steiner, Robert D. Blum ★ W33A is a well-known example of a high-mass young stellar object showing evidence of a circumstellar disc. We revisited the K-band NIFS/Gemini North observations of the W33A protostar using principal components analysis tomography and additional post-processing routines. Our results indicate the presence of a compact rotating disc based on the kinematics of the CO absorption features. The position-velocity

diagram shows that the disc exhibits a rotation curve with velocities that rapidly decrease for radii larger than 0.1 arcsec (∼250 AU) from the central source, suggesting a structure about four times more compact than previously reported. We derived a dynamical mass of $10.0^{+4.1}_{-2.2}$ $M_\odot$ for the "disc+protostar" system, about ∼33protostar status. A relatively compact H_2 wind was identified at the base of the large-scale outflow of W33A, with a mean visual extinction of ∼63 mag. By taking advantage of supplementary near-infrared maps, we identified at least two other point-like objects driving extended structures in the vicinity of W33A, suggesting that multiple active protostars are located within the cloud. The closest object (Source B) was also identified in the NIFS field of view as a faint point-like object at a projected distance of ∼7,000 AU from W33A, powering extended K-band continuum emission detected in the same field. Another source (Source C) is driving a bipolar H_2 jet aligned perpendicular to the rotation axis of W33A.

23. Resolving Structure in the Debris Disk around HD 206893 with ALMA

Ava Nederlander, A. Meredith Hughes, Anna J. Fehr, Kevin M. Flaherty, Kate Y. L. Su, Attila Moor, Eugene Chiang, Sean M. Andrews, David J. Wilner, Sebastian Marino ★ Debris disks are tenuous, dusty belts surrounding main sequence stars generated by collisions between planetesimals. HD 206893 is one of only two stars known to host a directly imaged brown dwarf orbiting interior to its debris ring, in this case at a projected separation of 10.4 au. Here we resolve structure in the debris disk around HD 206893 at an angular resolution of 0.6" (24 au) and wavelength of 1.3 mm with the Atacama Large Millimeter/submillimeter Array (ALMA). We observe a broad disk extending from a radius of < 51 au to 194^{+13}_{-2} au. We model the disk with a continuous, gapped, and double power-law model of the surface density profile, and find strong evidence for a local minimum in the surface density distribution near a radius of 70 au, consistent with a gap in the disk with an inner radius of 63^{+8}_{-16} au and width 31^{+11}_{-7} au. Gapped structure has been observed in four other debris disks – essentially every other radially resolved debris disk observed with sufficient angular resolution and sensitivity with ALMA – and could be suggestive of the presence of an additional planetary-mass companion.

24. Deciphering the 3-D Orion Nebula-III: Structure on the NE boundary of the Orion-S Embedded Molecular Cloud

C. R. O'Dell, G. J. Ferland, N. P. Abel ★ We have extended the work of Papers I and II of this series to determine at higher spatial resolution the properties of the embedded Orion-S Molecular Cloud that lies within the ionized cavity of the Orion Nebula and of the thin ionized layer that lies between the Cloud and the observer. This was done using existing and new [NII](658.3 nm) and [OIII] (500.7 nm) spectra that map the central region of the Orion Nebula (the Huygens Region). However, it remains unclear how the surface brightness of the ionized layer on the Orion-S Molecular Cloud and that of a foreground Nearer Ionized Layer are linked, as the observations show they must be. It is shown that the Cloud modifies the outer parts of the Huygens Region in the direction of the extended hot X-ray gas.

25. Deciphering the 3-D Orion Nebula-IV: The HH 269 flow emerges from the Orion-S Embedded Molecular Cloud

C. R. O'Dell, N. P. Abel, G. J. Ferland ★ We have extended the membership and determined the 3-D structure of the large (0.19 pc) HH 269 sequence of shocks in the Orion Nebula. All of the components lie along a track that is highly tilted to the plane-of-the-sky and emerge from within the Orion-S embedded molecular cloud. Their source is probably either the highly obscured mm 9 source associated with a high N2H+ density core (more likely) or the more distant star COUP 632 (less likely). The former must be located in the Photon Dominated Region (PDR) underlying the ionized surface of the Orion South Cloud, while the latter would be embedded within the cloud. The flows seem to be episodic, with intervals of 1900 to 2600 years or 700 to 2600 years if COUP 632 is the source.

26. Fiery Cores: Bursty and Smooth Star Formation Distributions across Galaxy Centers in Cosmological Zoom-in Simulations

Matthew E. Orr, H Perry Hatchfield, Cara Battersby, Christopher C. Hayward, Philip F. Hopkins, Andrew Wetzel, Samantha M. Benincasa, Sarah R. Loebman, Mattia C. Sormani, Ralf S. Klessen ★ We present an analysis of the $R \lesssim 1.5$ kpc core regions of seven simulated Milky Way mass galaxies, from the FIRE-2 (Feedback in Realistic Environments) cosmological zoom-in simulation suite, for a finely sampled period ($\Delta t = 2.2$ Myr) of 22 Myr at $z \approx 0$, and compare them with star formation rate (SFR) and gas surface density observations of the Milky Way's Central Molecular Zone (CMZ). Despite not being tuned to reproduce the detailed structure of the CMZ, we find that four of these galaxies are consistent with CMZ observations at some point during this 22 Myr period. The galaxies presented here are not homogeneous in their central structures, roughly dividing into two morphological classes; (a) several of the galaxies have very asymmetric gas and SFR distributions, with intense (compact) starbursts occurring over a period of roughly 10 Myr, and structures on highly eccentric orbits through the CMZ, whereas (b) others have smoother gas and SFR distributions, with only slowly varying SFRs over the period analyzed. In class (a) centers, the orbital motion of gas and star-forming complexes across small apertures ($R \lesssim 150$pc,

analogously $|l| < 1^\circ$ in the CMZ observations) contributes as much to tracers of star formation/dense gas appearing in those apertures, as the internal evolution of those structures does. These asymmetric/bursty galactic centers can simultaneously match CMZ gas and SFR observations, demonstrating that time-varying star formation can explain the CMZ's low star formation efficiency.

27. Constraining Protoplanetary Disk Accretion and Young Planets Using ALMA Kinematic Observations

Ian Rabago, Zhaohuan Zhu ★ Recent ALMA molecular line observations have revealed 3-D gas velocity structure in protoplanetary disks, shedding light on mechanisms of disk accretion and structure formation. 1) By carrying out viscous simulations, we confirm that the disk's velocity structure differs dramatically using vertical stress profiles from different accretion mechanisms. Thus, kinematic observations tracing flows at different disk heights can potentially distinguish different accretion mechanisms. On the other hand, the disk surface density evolution is mostly determined by the vertically integrated stress. The sharp disk outer edge constrained by recent kinematic observations can be caused by a radially varying α in the disk. 2) We also study kinematic signatures of a young planet by carrying out 3-D planet-disk simulations. The relationship between the planet mass and the "kink" velocity is derived, showing a linear relationship with little dependence on disk viscosity, but some dependence on disk height when the planet is massive, e.g. $10M_J$. We predict the "kink" velocities for the potential planets in DSHARP disks. At the gap edge, the azimuthally-averaged velocities at different disk heights deviate from the Keplerian velocity at similar amplitudes, and its relationship with the planet mass is consistent with that in 2-D simulations. After removing the planet, the azimuthally-averaged velocity barely changes within the viscous timescale, and thus the azimuthally-averaged velocity structure at the gap edge is due to the gap itself and not directly caused to the planet. Combining both axisymmetric kinematic observations and the residual "kink" velocity is needed to probe young planets in protoplanetary disks.

28. Accretion and outflow activity in proto-brown dwarfs

B. Riaz, J. Bally ★ We present a near-infrared study of accretion and outflow activity in 6 Class 0/I proto-brown dwarfs (proto-BDs) using VLT/SINFONI spectroscopy and spectro-imaging observations. The spectra show emission in several [FeII] and H_2 lines associated with jet/outflow activity, and in the accretion diagnostics of Paβ and Brγ lines. The peak velocities of the [FeII] lines (>100 km s^{-1}) are higher than the H_2 lines. The Class 0 proto-BDs show strong emission in the H_2 lines but the [FeII] lines are undetected, while the Class I objects show emission in both [FeII] and H_2 lines, suggesting an evolutionary trend in the jets from a molecular to an ionic composition. Extended emission with knots is seen in the [FeII] and H_2 spectro-images for 3 proto-BDs, while the rest show compact morphologies with a peak on-source. The accretion rates for the proto-BDs span the range of (2×10^{-6} – 2×10^{-8}) Msun yr^{-1}, while the mass loss rates are in the range of (4×10^{-8} – 5×10^{-9}) Msun yr^{-1}. These rates are within the range measured for low-mass protostars and higher than Class II brown dwarfs. We find a similar range in the jet efficiency for proto-BDs as measured in protostars. We have performed a study of the Brackett decrement from the Br7-Br19 lines detected in the proto-BDs. The upper Brackett lines of Br13-Br19 are only detected in the earlier stage systems. The ratios of the different Brackett lines with respect to the Brγ line intensity are consistent with the ratios expected from Case B recombination.

29. GASTON: Galactic Star Formation with NIKA2. Evidence for the mass growth of star-forming clumps

GASTON collaboration, A. J. Rigby et al. ★ Determining the mechanism by which high-mass stars are formed is essential for our understanding of the energy budget and chemical evolution of galaxies. By using the New IRAM KIDs Array 2 (NIKA2) camera on the Institut de Radio Astronomie Millimétrique (IRAM) 30-m telescope, we have conducted high-sensitivity and large-scale mapping of a fraction of the Galactic plane in order to search for signatures of the transition between the high- and low-mass star-forming modes. Here, we present the first results from the Galactic Star Formation with NIKA2 (GASTON) project, a Large Programme at the IRAM 30-m telescope which is mapping ≈2 deg^2 of the inner Galactic plane (GP), centred on ℓ=23.9°, b=0.05°, as well as targets in Taurus and Ophiuchus in 1.15 and 2.00 mm continuum wavebands. In this paper we present the first of the GASTON GP data taken, and present initial science results. We conduct an extraction of structures from the 1.15 mm maps using a dendrogram analysis and, by comparison to the compact source catalogues from Herschel survey data, we identify a population of 321 previously-undetected clumps. Approximately 80 per cent of these new clumps are 70 μm-quiet, and may be considered as starless candidates. We find that this new population of clumps are less massive and cooler, on average, than clumps that have already been identified. Further, by classifying the full sample of clumps based upon their infrared-bright fraction - an indicator of evolutionary stage - we find evidence for clump mass growth, supporting models of clump-fed high-mass star formation.

30. $C^{18}O$, ^{13}CO, and ^{12}CO abundances and excitation temperatures in the Orion B molecular cloud: An analysis of the precision achievable when modeling spectral line within the Local Thermodynamic Equilibrium approximation

Antoine Roueff, Maryvonne Gerin, Pierre Gratier, Francois Levrier, Jerome Pety, Mathilde Gaudel, Javier R. Goicoechea, Jan H. Orkisz, Victor de Souza Magalhaes, Maxime Vono, Sebastien Bardeau, Emeric Bron, Jocelyn Chanussot, Pierre Chainais, Viviana V. Guzman, Annie Hughes, Jouni Kainulainen, David Languignon, Jacques Le Bourlot, Franck Le Petit, Harvey S. Liszt, Antoine Marchal, Marc-Antoine Miville-Deschenes, Nicolas Peretto, Evelyne Roueff, Albrecht Sievers ★ CO isotopologue transitions are routinely observed in molecular clouds to probe the column density of the gas, the elemental ratios of carbon and oxygen, and to trace the kinematics of the environment. We aim at estimating the abundances, excitation temperatures, velocity field and velocity dispersions of the three main CO isotopologues towards a subset of the Orion B molecular cloud. We use the Cramer Rao Bound (CRB) technique to analyze and estimate the precision of the physical parameters in the framework of local-thermodynamic-equilibrium excitation and radiative transfer with an additive white Gaussian noise. We propose a maximum likelihood estimator to infer the physical conditions from the 1-0 and 2-1 transitions of CO isotopologues. Simulations show that this estimator is unbiased and efficient for a common range of excitation temperatures and column densities (Tex $>$ 6 K, N $>$ 1e14 - 1e15 cm-2). Contrary to the general assumptions, the different CO isotopologues have distinct excitation temperatures, and the line intensity ratios between different isotopologues do not accurately reflect the column density ratios. We find mean fractional abundances that are consistent with previous determinations towards other molecular clouds. However, significant local deviations are inferred, not only in regions exposed to UV radiation field but also in shielded regions. These deviations result from the competition between selective photodissociation, chemical fractionation, and depletion on grain surfaces. We observe that the velocity dispersion of the C18O emission is 10from the simultaneous analysis of two different rotational transitions of the same species is rigorously quantified. The CRB technique is a promising avenue for analyzing the estimation of physical parameters from the fit of spectral lines.

31. Dissecting the super-critical filaments embedded in the 0.5 pc subsonic region of B5

Anika Schmiedeke, Jaime E. Pineda, Paola Caselli, Héctor G. Arce, Gary A Fuller, Alyssa A. Goodman, María José Maureira, Stella S. R. Offner, Dominique Segura-Cox, Daniel Seifried ★ We characterize in detail the two 0.3 pc long filamentary structures found within the subsonic region of Barnard 5. We use combined GBT and VLA observations of the molecular lines NH_3(1,1) and (2,2) at a resolution of 1800 au, as well as JCMT continuum observations at 850 and 450 μm at a resolution of 4400 au and 3000 au, respectively. We find that both filaments are highly super-critical with a mean mass per unit length, M/L, of 80 $M_\odot$ pc^{-1}, after background subtraction, with local increases reaching values of 150 $M_\odot$ pc^{-1}. This would require a magnetic field strength of 500 μG to be stable against radial collapse. We extract equidistant cuts perpendicular to the spine of the filament and fit a modified Plummer profile as well as a Gaussian to each of the cuts. The filament widths (deconvolved FWHM) range between 6500-7000 au (0.03 pc) along the filaments. This equals 2.0 times the radius of the flat inner region. We find an anti-correlation between the central density and this flattening radius, suggestive of contraction. Further, we also find a strong correlation between the power-law exponent at large radii and the flattening radius. We note that the measurements of these three parameters fall in a plane and derive their empirical relation. Our high-resolution observations provide direct constraints of the distribution of the dense gas within super-critical filaments showing pre- and protostellar activity.

32. High-accuracy estimation of magnetic field strength in the interstellar medium from dust polarization

Raphael Skalidis, Konstantinos Tassis ★ Dust polarization is a powerful tool for studying the magnetic field properties in the interstellar medium (ISM). However, it does not provide a direct measurement of its strength. Different methods havebeen developed which employ both polarization and spectroscopic data in order to infer the field strength. The most widely applied methods have been developed by Davis (1951), Chandrasekhar & Fermi (1953) (DCF), Hildebrand et al. (2009) and Houde et al.(2009) (HH09). They rely on the assumption that isotropic turbulent motions initiate the propagation of Alvfén waves. Observations,however, indicate that turbulence in the ISM is anisotropic and non-Alfvénic (compressible) modes may be important. Our goal is to develop a new method for estimating the field strength in the ISM, which includes the compressible modes and does not contradict the anisotropic properties of turbulence. We use simple energetics arguments that take into account the compressible modes to estimate the strength of the magnetic field. We derive the following equation: $B_0 = \sqrt{2\pi\rho}\delta v/\sqrt{\delta\theta}$, where ρ is the gas density, δv is the rms velocity as derived from the spread of emission lines, and $\delta\theta$ is the dispersion of polarization angles. We produce synthetic observations from 3D MHD simulations and we assess the accuracy of our method by comparing the true field strength with the estimates derived from our equation. We find a mean relative deviation of 17%. The accuracy of our method does not depend on the turbulence properties of the simulated model. In contrast DCF and HH09 systematically overestimate the field strength. HH09 produces accurate results only for simulations with high sonic Mach numbers.

33. Outflows, envelopes, and disks as evolutionary indicators in Lupus YSOs

M. M. Vazzano, M. Fernández-López, A. Plunkett, I. de Gregorio-Monsalvo, A. Santamaría-Miranda, S. Takahashi, C. Lopez ★ By studying 7 objects in the Lupus clouds we aim to test if a coherence exists between commonly used evolutionary tracers. We present ALMA observations of the continuum and molecular line emission that probe the dense gas and dust of cores and their associated molecular outflows. Our source selection in a common environment allows for a consistent comparison across different evolutionary stages. The quality of the ALMA molecular data allows us to reveal the nature of the molecular outflows by studying their morphology and kinematics. The images in IRAS15398-3359 appear to show that it drives a precessing episodic jet-driven outflow with at least 4 ejections separated by periods of time between 50 and 80 years, while data in IRAS16059-3857 show similarities with a wide-angle wind model also showing signs of being episodic. The outflow of J160115-41523 could be better explain with the wide-angle wind model as well, but new observations are needed to explore its nature. We find that the most common evolutionary tracers are useful for broad evolutionary classifications, but are not consistent with each other to provide enough granularity to disentangle different evolutionary stage of sources that belong to the same Class. Outflow properties used as protostellar age tracers (mass, momentum, energy, opening angle) may suffer from differences in the nature of each outflow, thus detailed observations are needed to refine evolutionary classifications. We found both AzTEC-lup1-2 and AzTEC-lup3-5 to be in the pre-stellar stage, although the latter could be more evolved. IRAS15398-3359, IRAS16059-3857 and J160115-41523, which have clearly detected outflows, are Class 0 sources, although we are not able to determine which is younger and which is older. Sz102 and Merin28 are the most evolved sources and show signs of having associated flows, not as well traced by CO as for the younger sources.

34. Star formation in 'the Brick': ALMA reveals an active proto-cluster in the Galactic centre cloud G0.253+0.016

Daniel L. Walker, Steven N. Longmore, John Bally, Adam Ginsburg, J. M. Diederik Kruijssen, Qizhou Zhang, Jonathan D. Henshaw, Xing Lu, João Alves, Ashley T. Barnes, Cara Battersby, Henrik Beuther, Yanett A. Contreras, Laura Gómez, Luis C. Ho, James M. Jackson, Jens Kauffmann, Elisabeth A. C. Mills, Thushara Pillai ★ G0.253+0.016, aka 'the Brick', is one of the most massive ($> 10^5$ Msun) and dense ($> 10^4$ cm^{-3}) molecular clouds in the Milky Way's Central Molecular Zone. Previous observations have detected tentative signs of active star formation, most notably a water maser that is associated with a dust continuum source. We present ALMA Band 6 observations with an angular resolution of 0.13" (1000 AU) towards this 'maser core', and report unambiguous evidence of active star formation within G0.253+0.016. We detect a population of eighteen continuum sources (median mass 2 Msun), nine of which are driving bi-polar molecular outflows as seen via SiO (5-4) emission. At the location of the water maser, we find evidence for a protostellar binary/multiple with multi-directional outflow emission. Despite the high density of G0.253+0.016, we find no evidence for high-mass protostars in our ALMA field. The observed sources are instead consistent with a cluster of low-to-intermediate-mass protostars. However, the measured outflow properties are consistent with those expected for intermediate-to-high-mass star formation. We conclude that the sources are young and rapidly accreting, and may potentially form intermediate and high-mass stars in the future. The masses and projected spatial distribution of the cores are generally consistent with thermal fragmentation, suggesting that the large-scale turbulence and strong magnetic field in the cloud do not dominate on these scales, and that star formation on the scale of individual protostars is similar to that in Galactic disc environments.

35. The Milky Way Project: Probing Star Formation with First Results on Yellowballs from DR2

Grace Wolf-Chase, C. R. Kerton, Kathryn Devine, Anupa Pouydal, Johanna Mori, Leonardo Trujillo, Aurora Cossairt, Sarah Schoultz, Tharindu Jayasinghe, Matthew Povich ★ Yellowballs (YBs) were first discovered during the Milky Way Project citizen-science initiative (MWP; Simpson et al. 2012). MWP users noticed compact, yellow regions in Spitzer Space Telescope mid-infrared (MIR) images of the Milky Way plane and asked professional astronomers to explain these "yellow balls." Follow-up work by Kerton et al. (2015) determined that YBs likely trace compact photo-dissociation regions associated with massive and intermediate-mass star formation. YBs were included as target objects in a version of the Milky Way Project launched in 2016 (Jayasinghe et al. 2016), which produced a listing of over 6000 YB locations. We have measured distances, cross-match associations, physical properties, and MIR colors of 500 YBs within a pilot region covering the l= 30 - 40 degrees, b= +/- 1 degree region of the Galactic plane. We find 20-30high-mass star formation capable of becoming expanding H II regions that produce MIR bubbles. A majority of YBs represent intermediate-mass star-forming regions whose placement in evolutionary diagrams suggest they are still actively accreting, and may be precursors to optically-revealed Herbig Ae/Be nebulae. Many of these intermediate-mass YBs were missed by surveys of massive star-formation tracers and thus this catalog provides information for many new sites of star formation. Future work will expand this pilot region analysis to the entire YB catalog.

36. Formation and evolution of protostellar accretion discs. I. Angular-momentum budget, gravitational self-regulation, and numerical convergence

Wenrui Xu, Matthew W. Kunz ★ We investigate the formation and early evolution of a protostellar disc from a magnetized pre-stellar core using non-ideal magnetohydrodynamic (MHD) simulations including ambipolar diffusion and Ohmic dissipation. The dynamical contraction of the pre-stellar core ultimately leads to the formation of a first hydrostatic core, after ambipolar diffusion decouples the magnetic field from the predominantly neutral gas. The hydrostatic core accumulates angular momentum from the infalling material, evolving into a rotationally supported torus; this 'first hydrostatic torus' then forms an accreting protostar and a rotationally supported disc. The disc spreads out by gravitational instability, reaching ∼30 au in diameter at ∼3 kyr after protostar formation. The total mass and angular momentum of the protostar-disc system are determined mainly by accretion of gas from an infalling pseudo-disc, which has low specific angular momentum because of magnetic braking; their removal from the protostar-disc system by outflow and disc magnetic braking are negligible, in part because the magnetic field is poorly coupled there. The redistribution of angular momentum within the protostar-disc system is facilitated mainly by gravitational instability; this allows formation of relatively large discs even when the specific angular momentum of infalling material is low. We argue that such discs should remain marginally unstable as they grow (with Toomre $Q \sim$ 1-2), an idea that is broadly consistent with recent observational estimates for Class 0/I discs. We discuss the numerical convergence of our results, and show that properly treating the inner boundary condition is crucial for achieving convergence at an acceptable computational cost.

37. The Perseus ALMA Chemistry Survey (PEACHES). I. The Complex Organic Molecules in Perseus Embedded Protostars

Yao-Lun Yang, Nami Sakai, Yichen Zhang, Nadia M. Murillo, Ziwei E. Zhang, Aya E. Higuchi, Shaoshan Zeng, Ana López-Sepulcre, Satoshi Yamamoto, Bertrand Lefloch, Mathilde Bouvier, Cecilia Ceccarelli, Tomoya Hirota, Muneaki Imai, Yoko Oya, Takeshi Sakai, Yoshimasa Watanabe ★ To date, about two dozen low-mass embedded protostars exhibit rich spectra with complex organic molecule (COM) lines. These protostars seem to possess different enrichment in COMs. However, the statistics of COM abundance in low-mass protostars are limited by the scarcity of observations. This study introduces the Perseus ALMA Chemistry Survey (PEACHES), which aims at unbiasedly characterizing the chemistry of COMs toward the embedded (Class 0/I) protostars in the Perseus molecular cloud. Among the 50 embedded protostars surveyed, 58protostars have CH_3OH, CH_3OCHO, and N-bearing COMs, respectively. The detectability of COMs depends on neither the averaged continuum brightness temperature, a proxy of the H_2 column density, nor the bolometric luminosity and the bolometric temperature. For the protostars with detected COMs, CH_3OH has a tight correlation with CH_3CN, spanning more than two orders of magnitude in column densities normalized by the continuum brightness temperature, suggesting a chemical relation between CH_3OH and CH_3CN and large chemical diversity among the PEACHES samples at the same time. A similar trend with more scatter is also found between all identified COMs, hinting at common chemistry for the sources with COMs. The correlation between COMs is insensitive to the protostellar properties, such as the bolometric luminosity and the bolometric temperature. The abundance of larger COMs (CH_3OCHO and CH_3OCH_3) relative to that of smaller COMs (CH_3OH and CH_3CN) increases with the inferred gas column density, hinting at an efficient production of complex species in denser envelopes.

38. Low-metallicity Young Clusters in the Outer Galaxy. III. Sh 2-127

Chikako Yasui, Naoto Kobayashi, Masao Saito, Natsuko Izumi, Warren Skidmore ★ In deep near-infrared imaging of the low-metallicity ([O/H] = −0.7 dex) H II region Sh 2-127 (S127) with Subaru/MOIRCS, we detected two young clusters with 413 members (S127A) in a slightly extended H II region and another with 338 members (S127B) in a compact H II region. The limiting magnitude was $K = 21.3$ mag (10σ), corresponding to a mass detection limit of ∼0.2 $M_\odot$. These clusters are an order of magnitude larger than previously studied young low-metallicity clusters and larger than the majority of solar neighborhood young clusters. Fits to the K-band luminosity functions indicate very young cluster ages of 0.5 Myr for S127A and 0.1-0.5 Myr for S127B, consistent with the large extinction (up to $A_V \simeq 20$ mag) from thick molecular clouds and the presence of a compact H II region and class I source candidates, and suggest that the initial mass function (IMF) of the low-metallicity clusters is indistinguishable from typical solar neighborhood IMFs. Disk fractions of $28\% \pm 3\%$ for S127A and $40\% \pm 4\%$ for S127B are significantly lower than those of similarly aged solar neighborhood clusters (∼50%-60%). The disk fraction for S127B is higher than those of previously studied low-metallicity clusters (<30 %), probably due to S127B's age. This suggests that a large fraction of very young stars in low-metallicity environments have disks, but the disks are lost on a very short timescale. These results are consistent with our previous studies of low-metallicity star-forming regions, suggesting that a solar neighborhood IMF and low disk fraction are typical characteristics for low-metallicity regions, regardless of cluster scales.

39. **The Hawaii Infrared Parallax Program. V. New T-Dwarf Members and Candidate Members of Nearby Young Moving Groups**

Zhoujian Zhang, Michael C. Liu, William M. J. Best, Trent J. Dupuy, Robert J. Siverd ★ We present a search for new planetary-mass members of nearby young moving groups (YMGs) using astrometry for 694 T and Y dwarfs, including 447 objects with parallaxes, mostly produced by recent large parallax programs from UKIRT and Spitzer. Using the BANYAN Σ and LACEwING algorithms, we identify 30 new candidate YMG members, with spectral types of T0−T9 and distances of $10-43$ pc. Some candidates have unusually red colors and/or faint absolute magnitudes compared to field dwarfs with similar spectral types, providing supporting evidence for their youth, including 4 early-T dwarfs. We establish one of these, the variable T1.5 dwarf 2MASS J21392676+0220226, as a new planetary-mass member ($14.6^{+3.2}_{-1.6}$ M_{Jup}) of the Carina-Near group (200 ± 50 Myr) based on its full six-dimensional kinematics, including a new parallax measurement from CFHT. The high-amplitude variability of this object is suggestive of a young age, given the coexistence of variability and youth seen in previously known YMG T dwarfs. Our four latest-type (T8−T9) YMG candidates, WISE J031624.35+430709.1, ULAS J130217.21+130851.2, WISEPC J225540.74−311841.8, and WISE J233226.49−432510.6, if confirmed, will be the first free-floating planets ($\approx 2-6$ M_{Jup}) whose ages and luminosities are compatible with both hot-start and cold-start evolutionary models, and thus overlap the properties of the directly-imaged planet 51 Eri b. Several of our early/mid-T candidates have peculiar near-infrared spectra, indicative of heterogenous photospheres or unresolved binarity. Radial velocity measurements needed for final membership assessment for most of our candidates await upcoming 20−30 meter class telescopes. In addition, we compile all 15 known T7−Y1 benchmarks and derive a homogeneous set of their effective temperatures, surface gravities, radii, and masses.