The Star Formation Newsletter

A community newsletter on Star and Planet Formation research

No. 356 — 31 August 2022
Editor: João Alves www.starformation.news

Links to sections

Cover image caption

The Tarantula Nebula region in the Large Magellanic cloud (LMC) as seen from the VLT Survey Telescope at ESO's Paranal Observatory in Chile. At a distance of about 50 kpc, the LMC is the most remarkable feature of the LMC, containing the 30 Dor or R136 super star cluster. The region is a prime laboratory for star (and planet) formation, even more so with the arrival of the Extremely Large Telescopes in less than a decade. If the nebula were to be located at the distance of the Orion Nebula, it would be bright enough to cast a visible shadow during the night. The image is a color composite of g (480 nm), r (625 nm), i (770 nm), and H_α.

Credit: VLT Survey Telescope (VST) - ESO

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. ## Topography of the Young Galactic Disk: Spatial and Kinematic Patterns of the Clustered Star Formation in the Solar Neighborhood

Emilio J. Alfaro, Manuel Jiménez, Mari Carmen Sánchez-Gil, Néstor Sánchez, Marta González, Jesús Maíz Apellániz ★ The accuracy in determining the spatial-kinematical parameters of open clusters makes them ideal tracers of the Galactic structure. Young open clusters (YOCs) are the main representative of the clustered star formation mode, which identifies how most of the stars in the Galaxy form. We apply the Kriging technique to a sample of Gaia YOCs within a 3.5 kpc radius around the Sun and log(age) ≤ 7.5, age in years, to obtain the $Z(X,Y)$ and $V_Z(X,Y)$ maps. The previous work by Alfaro et al. (1991) showed that Kriging can provide reliable results even with small data samples ($N \sim 100$). We approach the 3D spatial and vertical velocity field structure of the Galactic disk defined by YOCs and analyze the hierarchy of the stellar cluster formation, which shows a rich hierarchical structure, displaying complexes embedded within each other. We discuss the fundamental characteristics of the methodology used to perform the mapping and point out the main results obtained in phenomenological terms. Both the 3D spatial distribution and the vertical velocity field reveal a complex disk structure with a high degree of substructures. Their analysis provides clues about the main physical mechanisms that shape the phase space of the clustered star formation in this Galactic area. Warp, corrugations, and high local deviations in Z and V_Z, appear intimately connected in a single but intricate scenario.

2. ## Near-infrared Accretion Signatures from the Circumbinary Planetary Mass Companion Delorme 1 (AB)b

S. K. Betti, K. B. Follette, K. Ward-Duong, Y. Aoyama, G. -D. Marleau, J. Bary, C. Robinson, M. Janson, W. Balmer, G. Chauvin, P. Palma-Bifani ★ Accretion signatures from bound brown dwarf and protoplanetary companions provide evidence for ongoing planet formation, and accreting substellar objects have enabled new avenues to study the astrophysical mechanisms controlling formation and accretion processes. Delorme 1 (AB)b, a 30-45 Myr circumbinary planetary mass companion, was recently discovered to exhibit strong Hα emission. This suggests ongoing accretion from a circumplanetary disk, somewhat surprising given canonical gas disk dispersal timescales of 5-10 Myr. Here, we present the first NIR detection of accretion from the companion in Paβ, Paγ, and Brγ emission lines from SOAR/TripleSpec 4.1, confirming and further informing its accreting nature. The companion shows strong line emission, with $L_{line} \approx 1 - 6 \times 10^{-8}$ $L_\odot$ across lines and epochs, while the binary host system shows no NIR hydrogen line emission ($L_{line} < 0.32 - 11 \times 10^{-7}$ $L_\odot$). Observed NIR hydrogen line ratios are more consistent with a planetary accretion shock than with local line excitation models commonly used to interpret stellar magnetospheric accretion. Using planetary accretion shock models, we derive mass accretion rate estimates

of $\dot{M}_{\rm pla} \sim 3\text{-}4 \times 10^{-8}$ $M_{\rm J}$ yr^{-1}, somewhat higher than expected under the standard star formation paradigm. Delorme 1 (AB)b's high accretion rate is perhaps more consistent with formation via disk fragmentation. Delorme 1 (AB)b is the first protoplanet candidate with clear (S/N∼5) NIR hydrogen line emission.

3. Evidence for an interaction between the Galactic Center clouds M0.10-0.08 and M0.11-0.11

Natalie O. Butterfield, Cornelia C. Lang, Adam Ginsburg, Mark R. Morris, Juergen Ott, Dominic A. Ludovici

★ We present high-resolution (2-3"; 0.1 pc) radio observations of the Galactic center cloud M0.10-0.08 using the Very Large Array at K and Ka band (25 and 36 GHz). The M0.10-0.08 cloud is located in a complex environment near the Galactic center Radio Arc and the adjacent M0.11-0.11 molecular cloud. From our data, M0.10-0.08 appears to be a compact molecular cloud (3 pc) that contains multiple compact molecular cores (5+; <0.4 pc). In this study we detect a total of 15 molecular transitions in M0.10-0.08 from the following molecules: NH3, HC3N, CH3OH, HC5N, CH3CN, and OCS. We have identified more than sixty 36 GHz CH3OH masers in M0.10-0.08 with brightness temperatures above 400 K and 31 maser candidates with temperatures between 100-400 K. We conduct a kinematic analysis of the gas using NH3 and detect multiple velocity components towards this region of the Galactic center. The bulk of the gas in this region has a velocity of 51.5 km/s (M0.10-0.08) with a lower velocity wing at 37.6 km/s. We also detect a relatively faint velocity component at 10.6 km/s that we attribute to being an extension of the M0.11-0.11 cloud. Analysis of the gas kinematics, combined with past X-ray fluorescence observations, suggests M0.10-0.08 and M0.11-0.11 are located in the same vicinity of the Galactic center and could be physically interacting.

4. PENELLOPE III. The peculiar accretion variability of XX Cha and its impact on the observed spread of accretion rates

R. A. B. Claes, C. F. Manara, R. Garcia-Lopez, A. Natta, M. Fang, Z. P. Fockter, P. Ábrahám, J. M. Alcalá, J. Campbell-White, A. Caratti o Garatti, E. Covino, D. Fedele, A. Frasca, J. F. Gameiro, G. J. Herczeg, Á. Kóspál, M. G. Petr-Gotzens, G. Rosotti, L. Venuti, G. Zsidi

★ The processes regulating protoplanetary disk evolution are constrained by studying how mass accretion rates scale with stellar and disk properties. The spread in these relations can be used as a constraint to the models of disk evolution, but only if the impact of accretion variability is correctly accounted for. While the effect of variability might be substantial in the embedded phases of star formation, it is often considered limited at later stages. Here we report on the observed large variation in the accretion rate for one target, XX Cha, and we discuss the impact on population studies of classical T Tauri stars. The mass accretion rate determined by fitting the UV-to-near-infrared spectrum in recent X-Shooter observations is compared with the one measured with the same instrument 11 years before. XX Cha displays an accretion variability of almost 2 dex between 2010 and 2021. Although the timescales on which this variability happens are uncertain, XX Cha displays an extreme accretion variability for a classical T Tauri star. If such behavior is common among classical T Tauri stars, possibly on longer timescales than previously probed, it could be relevant for discussing the disk evolution models constrained by the observed spread in accretion rates. Finally, we remark that previous studies of accretion variability based on spectral lines may have underestimated the variability of some targets.

5. Evolution of the Hub-filament Structures in IC 5146 in the Context of the Energy Balance of Gravity, Turbulence, and Magnetic Field

Eun Jung Chung, Chang Won Lee, Woojin Kwon, Hyunju Yoo, Archana Soam, Jungyeon Cho

★ We present the results of 850 μm polarization and $C^{18}O$ (3-2) line observations toward the western hub-filament structure (W-HFS) of the dark Streamer in IC 5146 using the James Clerk Maxwell Telescope (JCMT) SCUBA-2/POL-2 and HARP instruments. We aim to investigate how the relative importance of the magnetic field, gravity, and turbulence affects core formation in HFS by comparing the energy budget of this region. We identified four 850 μm cores and estimated the magnetic field strengths ($B_{\rm pos}$) of the cores and the hub and filament using the Davis-Chandrasekhar-Fermi method. The estimated $B_{\rm pos}$ is ∼80 to 1200 μG. From Wang et al., $B_{\rm pos}$ of E-47, a core in the eastern hub (E-hub), and E-hub were re-estimated to be 500 and 320 μG, respectively, with the same method. We measured the gravitational ($E_{\rm G}$), kinematic ($E_{\rm K}$), and magnetic energies ($E_{\rm B}$) in the filament and hubs and compared the relative importance among them. We found that an $E_{\rm B}$-dominant filament has *aligned* fragmentation type, while $E_{\rm G}$-dominant hubs show *no* and *clustered* fragmentation types. In the $E_{\rm G}$ dominant hubs, it seems that the portion of $E_{\rm K}$ determines whether the hub becomes to have *clustered* (the portion of $E_{\rm K} \sim 20\%$) or *no* fragmentation type ($\sim 10\%$). We propose an evolutionary scenario for the E- and W-HFSs, where the HFS forms first by the collision of turbulent flows, and then the hubs and filaments can go into various types of fragmentation depending on their energy balance of gravity, turbulence, and magnetic field.

6. Evolution of the Hub-filament Structures in IC 5146 in the Context of the Energy Balance of Gravity, Turbulence, and Magnetic Field

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7. The galaxy-wide stellar initial mass function in the presence of cluster-to-cluster IMF variations

Sami Dib ★ We calculate the integrated galactic initial stellar mass function (IGIMF) in the presence of IMF variations in clusters. IMF Variations for a population of clusters are taken into account in the form of Gaussian distributions of the IMF parameters. For the tapered power law function used here, these are the slopes at the high and low mass ends, Γ and γ, and the characteristic mass M_{ch}. Variations are modeled by varying the width of the Gaussian distributions. The reference values are the standard deviations of the parameters observed for young clusters in the present-day Milky Way $\sigma_\Gamma = 0.6$, $\sigma_\gamma = 0.25$, and $\sigma_{M_{ch}} = 0.27$ $M_\odot$. Increasing the dispersions of γ and Γ moderately flattens the IGIMF at the low and high mass ends. Increasing $\sigma_{M_{ch}}$ shifts the peak of the IGIMF to lower masses, rendering the IGIMF more bottom heavy. This can explain the bottom heavy stellar mass function of Early-type galaxies as they are the result of the merger of disk galaxies where the physical conditions of the star forming gas vary significantly both in time and space. The effect of IMF variations is compared to that due to other effects such as variations in the shape of the initial cluster mass function, metallicity, and galactic SFR. We find that the effect of IMF variations is a dominant factor that always affects the characteristic mass of the IGIMF. We compare our results to a sample of ultra-faint dwarf satellite galaxies (UFDs). Their present-day stellar mass function is an analog to their IGIMF at the time their stellar populations have formed. We show that the slope of the IGIMF of the UFDs can only be reproduced when IMF variations of the same order as those measured in the present-day Milky Way are included. (Abridged)

8. The He I λ10830 Å line as a probe of winds and accretion in young stars in Lupus and Upper Scorpius

J. Erkal, C. F. Manara, P. C. Schneider, M. Vincenzi, B. Nisini, D. Coffey, J. M. Alcalá, D. Fedele, S. Antoniucci ★ The He I 1 micron line is a high excitation line which allows us to probe the innermost regions of protostellar disks, and to trace both accreting and outflowing material. We use X-Shooter observations of a sample of 107 young stars in the Lupus (1-3 Myr) and Upper Scorpius (5-10 Myr) star-forming regions to search for correlations between the line properties, as well as the disk inclination and accretion luminosity. We identified eight distinct profile types in the sample. We fitted Gaussian curves to the line features to measure the maximum velocities traced in absorption, the full-width half-maximum (FWHM) of the line features, and the Gaussian area of the features. We compare the proportion of each profile type in our sample to previous studies in Taurus. We find significant variations between Taurus and Lupus in the proportion of P Cygni and inverse P Cygni profiles, and between Lupus and Upper Scorpius in the number of emission-only and combination profile types. We find that the blue-shifted absorption features appear less blue-shifted at disk inclinations close to edge-on, but no such trend with inclination is observed in sources with only red-shifted features. Higher accretion rates were observed in sources with strong blue-shifted features which, along with the changes in the proportions of each profile type observed in the two regions, indicates that younger sources may drive stronger jets or winds. Overall, we observe variations in the proportion of each profile type and in the line properties which indicates and evolution of accretion and ejection signatures over time, and with source properties. These results confirm past works and models of the He I line, but for a larger sample and for multiple star-forming regions. The work highlights the power of the He I line as a probe of the gas in the innermost regions of the disk.

9. Chemical evolution in ices on drifting, planet-forming pebbles

Christian Eistrup, Thomas Henning ★ Planets and their atmospheres are built from gas and solid material in protoplanetary disks. Recent results suggest that solid material like pebbles may contribute significantly to building up planetary atmospheres. In order to link observed exoplanet atmospheres and their compositions to their formation histories, it is important to understand how icy pebbles may change their composition when they drift radially inwards in disks. Our goal is to model the compositional evolution of ices on pebbles as they drift in disks, and track how their chemical evolution en-route changes the ice composition relative to the ice composition of the pebbles in the region where they grew from micron-sized grains. A state-of-the-art chemical kinetics code is utilised for modelling chemical evolution. This code accounts for the time-evolving sizes of the solids that drift. Chemical evolution is modelled locally for 0.1Myr at two starting radii, with the micron-sized solids growing into pebbles simultaneously. The pebbles and local gas, isolated as a parcel, is then exposed to changing physical conditions, intended to mimic the pebbles drifting inwards in the disk midplane, moving to 1 AU on three different timescales. A modelling simplification is that the pebbles are *not* moved through, and exposed to new gas, but stay in the same chemical gas surroundings in all models. For ice species with initial abundances relative to hydrogen of $> 10^{-5}$, such as H_2O, CO_2, CH_3OH and NH_3, the abundances change by less than 20timescales (10kyr and 100kyr). For less abundant ice species, and the longest drift timescale (1Myr), the changes are larger. Pebble drift chemistry generally increases the ice abundances of CO_2, HCN and SO, at the expense of decreasing abundances of other volatile molecules.

10. Gap Opening and Inner Disk Structure in the Strongly Accreting Transition Disk of DM Tau

Logan Francis, Nienke van der Marel, Doug Johnstone, Eiji Akiyama, Simon Bruderer, Ruobing Dong, Jun Hashimoto, Hauyu Baobab Liu, Takayuki Muto, Yi Yang ★ Large inner dust gaps in transition disks are frequently posited as evidence of giant planets sculpting gas and dust in the disk, or the opening of a gap by photoevaporative winds. Although the former hypothesis is strongly supported by the observations of planets and deep depletions in gas within the gap some disks, many T Tauri stars hosting transition disks accrete at rates typical for an undepleted disk, raising the question of how gap opening occurs in these objects. We thus present an analysis of the structure of the transition disk around the T Tauri star DM Tau, which is strongly accreting ($\sim 10^{-8.3}$ $M_\odot$ yr^{-1}) and turbulent ($\alpha = 0.078 \pm 0.02$). Using the DALI thermochemical code, we fit disk models to simultaneously reproduce the accretion rate, high level of turbulence, the gas traced by ALMA band 6 observations of ^{12}CO, ^{13}CO, and $C^{18}O$ J=2–1 lines, and the observed dust emission from the mm continuum and spectral energy distribution. We find a shallow depletion in gas surface density of ~ 10 relative to the outer disk and a gas rich inner disk is consistent with the observations. The planet mass of < 1 M_{Jup} implied by the gap depth is in tension with predictions for dust trapping in a highly viscous disk, which requires a more massive planet of of $\sim 10 M_{Jup}$. Photoevaporative models including a dead zone can qualitatively reproduce some features of the DM Tau disk, but still struggle to explain the high accretion rates and the observed mm continuum flux.

11. Cosmic-ray ionization rate in protoplanetary disks with sheared magnetic fields

Yuri I. Fujii, Shigeo S. Kimura ★ We investigate the effects of magnetic field configurations on the ionization rate by cosmic rays in protoplanetary disks. First, we consider cosmic-ray propagation from the interstellar medium (ISM) to the protoplanetary disks and showed that the cosmic-ray density around the disk should be 4 times lower than the ISM value. Then, we compute the attenuation of cosmic rays in protoplanetary disks. The magnetic fields in the disk are stretched to the azimuthal directions, and cosmic rays need to detour while propagating to the midplane. We show that the detouring effectively enhances the column density by about two orders of magnitudes. In the case of the disk around IM lup, this increases the ionization rate over an order of magnitude for $r \gtrsim 100$ au. On the other hand, for $r \lesssim 100$ au, the cosmic rays are shielded at the disk midplane while the ionization rate is also enhanced at $z \sim 2H$. Our results are consistent with the recent ALMA observation that indicates the radial gradient in the cosmic-ray ionization rate. The elevated ionization rate in the outer radii of disks may activate the magnetorotational instability that was thought to be suppressed due to ambipolar diffusion. These results will have a strong influence on the dynamical and chemical evolutions of protoplanetary disks.

12. Monitoring accretion rate variability in the Orion Nebula Cluster with the Wendelstein Wide Field Imager

S. Flaischlen, T. Preibisch, M. Kluge, C. F. Manara, B. Ercolano ★ The understanding of the accretion process has a central role in the understanding of star and planet formation. We aim to test how accretion variability influences previous correlation analyses of the relation between X-ray activity and accretion rates, which is important for understanding the evolution of circumstellar disks and disk photoevaporation. We monitored accreting stars in the Orion Nebula Cluster from November 24, 2014, until February 17, 2019, for 42 epochs with the Wendelstein Wide Field Imager in the Sloan Digital Sky Survey u'g'r' filters on the 2 m Fraunhofer Telescope on Mount Wendelstein. Mass accretion rates were determined from the measured ultraviolet excess. The influence of the mass accretion rate variability on the relation between X-ray luminosities and mass accretion rates was analyzed statistically. We find a typical interquartile range of 0.3 dex for the mass accretion rate

variability on timescales from weeks to 2 years. The variability has likely no significant influence on a correlation analysis of the X-ray luminosity and the mass accretion rate observed at different times when the sample size is large enough. The observed anticorrelation between the X-ray luminosity and the mass accretion rate predicted by models of photoevaporation-starved accretion is likely not due to a bias introduced by different observing times.

13. Methanol deuteration in high-mass protostars

M. L. van Gelder, J. Jaspers, P. Nazari, A. Ahmadi, E. F. van Dishoeck, M. T. Beltrán, G. A. Fuller, Á. Sánchez-Monge, P. Schilke ★ The deuteration of molecules forming in the ices such as methanol (CH_3OH) is sensitive to the physical conditions during their formation in dense cold clouds and can be probed through observations of deuterated methanol in hot cores. Observations with ALMA containing transitions of CH_3OH, CH_2DOH, CHD_2OH, $^{13}CH_3OH$, and $CH_3^{18}OH$ are investigated. The column densities of CH_2DOH, CHD_2OH, and CH_3OH are determined for all sources, where the column density of CH_3OH is derived from optically thin ^{13}C and ^{18}O isotopologues. Consequently, the D/H ratio of methanol is derived taking statistical effects into account. Singly deuterated methanol (CH_2DOH) is detected toward 25 of the 99 sources in our sample of the high-mass protostars. Including upper limits, the $(D/H)_{CH_3OH}$ ratio inferred from N_{CH_2DOH}/N_{CH_3OH} was derived for 38 of the 99 sources and varies between $\sim 10^{-3} - 10^{-2}$. Including other high-mass hot cores from the literature, the mean methanol D/H ratio is $1.1 \pm 0.7 \times 10^{-3}$. This is more than one order of magnitude lower than what is seen for low-mass protostellar systems ($2.2 \pm 1.2 \times 10^{-2}$). Doubly deuterated methanol (CHD_2OH) is detected toward 11 of the 99 sources. Including upper limits for 15 sources, the $(D/H)_{CH_2DOH}$ ratios derived from N_{CHD_2OH}/N_{CH_2DOH} are more than two orders of magnitude higher than $(D/H)_{CH_3OH}$ with an average of $2.0 \pm 0.8 \times 10^{-1}$ which is similar to what is found for low-mass sources. Comparison with literature GRAINOBLE models suggests that the high-mass prestellar phases are either warm (> 20 K) or live shorter than the free-fall timescale. In contrast, for low-mass protostars, both a low temperature of < 15 K and a prestellar phase timescale longer than the free-fall timescale are necessary.

14. Methanol deuteration in high-mass protostars

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15. CO(J = 1-0) Observations toward the Filamentary Cloud in the Galactic Region of $153.60° \leqslant l \leqslant 156.50°$ and $1.85° \leqslant b \leqslant 3.50°$

Weihua Guo, Xuepeng Chen, Jiancheng Feng, Li Sun, Shiyu Zhang, Chen Wang, Yang Su, Yan Sun, Qingzeng Yan, Shaobo Zhang, Xin Zhou, MiaoMiao Zhang, Min Fang, Ji Yang ★ We present observations of J=1-0 transition lines of ^{12}CO, ^{13}CO, and $C^{18}O$ towards the Galactic region of $153.60° \leqslant l \leqslant 156.50°$ and $1.85° \leqslant b \leqslant 3.50°$, using the Purple Mountain Observatory (PMO) 13.7 m millimeter telescope. Based on the data, one main filament and five sub-filaments are found together as a network structure in the velocity interval of $[-42.5, -30.0]\,km\,s^{-1}$. The kinematic distance of this molecular cloud (MC) is estimated to be ~ 4.5 kpc. The median length, width, excitation temperature, line mass of these filaments are ~ 49 pc, ~ 2.9 pc, ~ 8.9 K, and $\sim 39\,M_\odot pc^{-1}$, respectively. The velocity structures along these filaments exhibit oscillatory patterns, which are likely caused by the fragmentation or accretion process along these filaments. The maximum accretion rate is estimated to be as high as $\sim 700\,M_\odot pc^{-1}$. A total of ~ 162 clumps and ~ 103 young stellar objects (YSOs) are identified in this region. Most of the clumps are in gravitationally bound states. Three H_{II} regions (G154.359+2.606, SH2-211, SH2-212) are found to be located in the apexes of the filaments. Intense star forming activities are found along the entire filamentary cloud. The observed results may help us to better understand the link between filaments and massive star formation.

16. Time-dependent, long-term hydrodynamic simulations of the inner protoplanetary disk II: The importance of stellar rotation

Lukas Gehrig, Daniel Steiner, Eduard Vorobyov, Manuel Güdel ★ The spin evolution of young protostars, surrounded by an accretion disk, still poses problems for observations and theoretical models. In recent studies, the importance of the magnetic star-disk interaction for stellar spin evolution has been elaborated. The accretion disk in these studies, however, is only represented by a simplified model and important features are not considered. We combined the implicit hydrodynamic TAPIR disk code with a stellar spin evolution model. The influence of stellar magnetic fields on the disk dynamics, the radial position of the inner disk radius, as well as the influence of stellar rotation on the disk were calculated self-consistently. Within a defined parameter space, we can reproduce the majority of fast and slow rotating stars observed in young stellar clusters. Additionally, the back reaction of different stellar spin evolutionary tracks on the disk can be analyzed. Disks around fast rotating stars are located closer to the star. Consequently, the disk midplane temperature in the innermost disk region increases significantly compared to slow rotating stars. We can show the effects of stellar rotation on episodic accretion outbursts. The higher temperatures of disks around fast rotating stars result in more outbursts and a longer outbursting period over the disk lifetime. The combination of a long-term hydrodynamic disk and a stellar spin evolution model allows the inclusion of previously unconsidered effects such as the back-reaction of stellar rotation on the long-term disk evolution and the occurrence of accretion outbursts. However, a wider parameter range has to be studied to further investigate these effects. Additionally, a possible interaction between our model and a more realistic stellar evolution code (e.g., the MESA code) can improve our understanding of the stellar spin evolution and its effects on the pre-main sequence star.

17. The effect of metallicity on the abundances of molecules in protoplanetary disks

R. Guadarrama, Eduard I. Vorobyov, Christian Rab, Manuel Güdel ★ We study the influence of different metallicities on the physical, thermal, and chemical properties of protoplanetary disks, and in particular on the formation and destruction of carbon-based molecules. With the thermo-chemical code ProoDIMO we investigate the impact of lower metallicities on the radiation field, disk temperature, and the abundance of different molecules (H_2O, CH_4, CO, CO_2, HCN, CN, HCO^+ and N_2H^+). We use a fiducial disk model as a reference model and produce two models with lower metallicity. The resulting influence on different chemical species is studied by analyzing their abundance distribution throughout the disk and their vertical column density. Furthermore, the formation and destruction reactions of the chemical species are studied. The results show a relation between the metallicity of the disk and the strength of the stellar radiation field inside the disk. As the metallicity decreases the radiation field is able to penetrate deeper regions of the disk. As a result, there is a stronger radiation field overall in the disk with lower metallicity which also heats up the disk. This triggers a series of changes in the chemical formation and destruction efficiencies for different chemical species. In most cases, the available species abundances change and have greater values compared to scaled-down abundances by constant factors. Metallicity has a clear impact on the snowline of the molecules studied here as well. As metallicity decreases the snowlines are pushed further out and existing snow rings shrink in size.

18. Exponentially amplified magnetic field eliminates disk fragmentation around the Population III protostar

Shingo Hirano, Masahiro N. Machida ★ One critical remaining issue to unclear the initial mass function of the first (Population III) stars is the final fate of secondary protostars formed in the accretion disk, specifically whether they merge or survive. We focus on the magnetic effects on the first star formation under the cosmological magnetic field. We perform a suite of ideal magnetohydrodynamic simulations until 1000 years after the first protostar formation. Instead of the sink particle technique, we employ a stiff equation of state approach to represent the magnetic field structure connecting to protostars. Ten years after the first protostar formation in the cloud initialized with $B_0 = 10^{-20}$ G at $n_0 = 10^4\,\mathrm{cm}^{-3}$, the magnetic field strength around protostars amplifies from pico- to kilo-gauss, which is the same strength as the present-day star. The magnetic field rapidly winds up since the gas in the vicinity of the protostar (≤ 10 au) has undergone several tens orbital rotations in the first decade after protostar formation. As the mass accretion progresses, the vital magnetic field region extends outward, and the magnetic braking eliminates fragmentation of the disk that would form in the unmagnetized model. On the other hand, assuming a gas cloud with small angular momentum, this amplification might not work because the rotation would be slower. However, disk fragmentation would not occur in that case. We conclude that the exponential amplification of the cosmological magnetic field strength, about 10^{-18} G, eliminates disk fragmentation around the Population III protostars.

19. Universal Properties of Dense Clumps in Magnetized Molecular Clouds Formed through Shock Compression of Two-phase Atomic Gases

Kazunari Iwasaki, Kengo Tomida ★ We investigate the formation of molecular clouds from atomic gas by using three-dimensional magnetohydrodynamical simulations,including non-equilibrium chemical reactions, heating/cooling processes, and self-gravity by changing the collision speed V_0 and the angle θ between the magnetic field and colliding flow. We found that the efficiency of the dense gas formation depends on θ. For small θ, anisotropic super-Alfvénic turbulence delays the formation of gravitationally unstable clumps. An increase in θ develops shock-amplified magnetic fields along which the gas is accumulated,

making prominent filamentary structures. We further investigate the statistical properties of dense clumps identified with different density thresholds. The statistical properties of the dense clumps with lower densities depend on V_0 and θ because their properties are inherited from the global turbulence structure of the molecular clouds. By contrast, denser clumps appear to have asymptotic universal statistical properties, which do not depend on the properties of the colliding flow significantly. The internal velocity dispersions approach subsonic and plasma β becomes order of unity. We develop an analytic formula of the virial parameter which reproduces the simulation results reasonably well. This property may be one of the reasons for the universality of the initial mass function of stars.

20. Inferring the Gas-to-Dust Ratio in the Main Planet-Forming Region of Disks

Adam S. Jermyn, Mihkel Kama ★ Measuring the amount of gas and dust in protoplanetary disks is a key challenge in planet formation studies. Here we provide a new set of dust depletion factors and relative mass surface densities of gas and dust for the innermost regions of a sample of protoplanetary disks. We do this by combining stellar theory with observed refractory element abundances in both disk hosts and open cluster stars. Our results are independent of, and complementary to, those obtained from spatially resolved disk observations.

21. Synthetic ngVLA line observations of a massive star-forming cloud

M. Juvela, E. Mannfors, T. Liu, L. V. Toth ★ Study of pre-stellar cloud evolution requires observations with high sensitivity and resolution, and regions of high-mass star formation are particularly challenging. We wish to quantify, to what accuracy the physical conditions within a massive star-forming cloud can be determined from observations. We are particularly interested in the possibilities offered by the Next Generation VLA (ngVLA) interferometer. We use data from a magnetohydrodynamic simulation of star-formation and concentrate on a filamentary structure that has physical properties similar to an infrared-dark cloud. We produce synthetic ngVLA observations of spectral lines and analyse the column density, gas temperature, and kinematics. The results are compared to ideal observations and the actual 3D model. For a distance of 4 kpc, ngVLA provides a resolution of 0.01 pc even in its most compact configuration. For abundant molecules, such as HCO+, NH3, N2H+, and CO isotopomers, cloud kinematics and structure can be mapped down to sub-arcsec scales. For NH3, a reliable column density map could be obtained for the entire 15 * 40 arcsec cloud, even without additional single-dish data, and kinetic temperatures are recovered to a precision of 1 K. At higher frequencies, the loss of large-scale emission is noticeable. The line observations accurately trace the cloud kinematics, except for the largest scales. The line-of-sight confusion complicates the interpretation of the kinematics, and limits the usefulness of collapse indicators based on the blue asymmetry of optically thick lines. The ngVLA will provide accurate data on the small-scale structure and the physical and chemical state of clouds, even in high-mass star-forming regions at kiloparsec distances. Complementary single-dish data are still essential for estimates of the total column density and the large-scale kinematics.

22. The eclipse of the V773 Tau B circumbinary disk

M. A. Kenworthy, D. González Picos, E. Elizondo, R. G. Martin, D. M. van Dam, J. E. Rodriguez, G. M. Kennedy, C. Ginski, M. Mugrauer, N. Vogt, C. Adam, R. J. Oelkers ★ A deep (70%) and extended (150 days) eclipse was seen towards the young multiple stellar system V773 Tau in 2010. We interpret it as due to the passage of a circumbinary disk around the B components moving in front of the A components. Our aim is to characterise the orientation and structure of the disk, to refine the orbits of the subcomponents, and to predict when the next eclipse will occur. We combine the photometry from several ground based surveys, construct a model for the light curve of the eclipse, and use high angular resolution imaging to refine the orbits of the three components of the system, A, B and C. Frequency analysis of the light curves, including from the TESS satellite, enables characterisation of the rotational periods of the Aa and Ab stars. A toy model of the circumbinary disk shows that it extends out to approximately 5 au around the B binary and has an inclination of 73 degrees with respect to the orbital plane of AB, where the lower bound of the radius of the disk is constrained by the geometry of the AB orbit and the upper bound is set by the stability of the disk. We identify several frequencies in the photometric data that we attribute to rotational modulation of the Aa and Ab stellar companions. We produce the first determination of the orbit of the more distant C component around the AB system and limit its inclination to 93 degrees. The high inclination and large diameter of the disk, together with the match from theory suggest that B is an almost equal mass, moderately eccentric binary. We identify the rotational periods of the Aa and Ab stars, identify a third frequency in the light curve that we attribute to the orbital period of the stars in the B binary. We predict that the next eclipse will be around 2037, during which both detailed photometric and spectroscopic monitoring will characterise the disk in greater detail.

23. Implementation of dust particles in three-dimensional magnetohydrodynamics simulation: Dust dynamics in a collapsing cloud core

Shunta Koga, Yoshihiro Kawasaki, Masahiro N. Machida ★ The aim of this study is to examine dust dynamics on a large scale and investigate the coupling of dust with gas fluid in the star formation process. We propose a method for calculating the dust trajectory in a gravitationally collapsing cloud, where the dust grains are treated as Lagrangian particles and are assumed to be neutral. We perform the dust trajectory calculations in combination with non-ideal magnetohydrodynamics simulation. Our simulation shows that dust particles with a size of $\leq 10\,\mu$m are coupled with gas in a star-forming cloud core. We investigate the time evolution of the dust-to-gas mass ratio and the Stokes number, which is defined as the stopping time normalized by the freefall time-scale, and show that large dust grains ($\gtrsim 100\,\mu$m) have a large Stokes number (close to unity) and tend to concentrate in the central region (i.e., protostar and rotationally supported disk) faster than do small grains ($\lesssim 10\,\mu$m). Thus, large grains significantly increase the dust-to-gas mass ratio around and inside the disk. We also confirm that the dust trajectory calculations, which trace the physical quantities of each dust particle, reproduce previously reported results obtained using the Eulerian approach.

24. Dynamics of magnetized accretion disks of young stars

Sergey A. Khaibrakhmanov, Alexander E. Dudorov ★ We investigate the dynamics of the accretion disks of young stars with fossil large-scale magnetic field. The author's magnetohydrodynamic (MHD) model of the accretion disks is generalized to consider the dynamical influence of the magnetic field on gas rotation speed and vertical structure of the disks. With the help of the developed MHD model, the structure of an accretion disk of a solar mass T Tauri star is simulated for different accretion rates $\dot{M}$ and dust grain sizes a_d. The simulations of the radial structure of the disk show that the magnetic field in the disk is kinematic, and the electromagnetic force does not affect the rotation speed of the gas for typical values $\dot{M} = 10^{-8}\,M_\odot\,\mathrm{yr}^{-1}$ and $a_d = 0.1\mu$m. In the case of large dust grains, $a_d \geq 1$ mm, the magnetic field is frozen into the gas and a dynamically strong magnetic field is generated at radial distances from the star $r \gtrsim 30$ au, the tensions of which slow down the rotation speed by $\lesssim 1.5$ % of the Keplerian velocity. This effect is comparable to the contribution of the radial gradient of gas pressure and can lead to the increase in the radial drift velocity of dust grains in the accretion disks. In the case of high accretion rate, $\dot{M} \geq 10^{-7}\,M_\odot\,\mathrm{yr}^{-1}$, the magnetic field is also dynamically strong in the inner region of the disk, $r < 0.2$ au. The simulations of the vertical structure of the disk show that, depending on the conditions on the surface of the disk, the vertical gradient of magnetic pressure can lead to both decrease and increase in the characteristic thickness of the disk as compared to the hydrostatic one by 5-20 %. The change in the thickness of the disk occurs outside the region of low ionization fraction and effective magnetic diffusion ('dead' zone), which extends from $r = 0.3$ to 20 au at typical parameters.

25. Primordial Dusty Rings and Episodic Outbursts in Protoplanetary Discs

Kundan Kadam, Eduard Vorobyov, Shantanu Basu ★ We investigate the formation and evolution of "primordial" dusty rings occurring in the inner regions of protoplanetary discs, with the help of long-term, coupled dust-gas, magnetohydrodynamic simulations. The simulations are global and start from the collapse phase of the parent cloud core, while the dead zone is calculated via an adaptive α formulation by taking into account the local ionization balance. The evolution of the dusty component includes its growth and back reaction on to the gas. Previously, using simulations with only a gas component, we showed that dynamical rings form at the inner edge of the dead zone. We find that when dust evolution as well as magnetic field evolution in the flux-freezing limit are included, the dusty rings formed are more numerous and span a larger radial extent in the inner disc, while the dead zone is more robust and persists for a much longer time. We show that these dynamical rings concentrate enough dust mass to become streaming unstable, which should result in rapid planetesimal formation even in the embedded phases of the system. The episodic outbursts caused by the magnetorotational instability have significant impact on the evolution of the rings. The outbursts drain the inner disc of grown dust, however, the period between bursts is sufficiently long for the planetesimal growth via streaming instability.The dust mass contained within the rings is large enough to ultimately produce planetary systems with the core accretion scenario. The low mass systems rarely undergo outbursts and thus, the conditions around such stars can be especially conducive for planet formation.

26. Growing the seeds of pebble accretion through planetesimal accretion

Sebastian Lorek, Anders Johansen ★ We explore the growth of planetary embryos by planetesimal accretion up to and beyond the point where pebble accretion becomes efficient at the so-called Hill-transition mass. Both the transition mass and the characteristic mass of planetesimals formed by the streaming instability increase with increasing distance from the star. We developed a model for the growth of a large planetesimal (embryo) embedded in a population of smaller planetesimals formed in a filament by the streaming instability. The model includes in a self-consistent way the collisional mass growth of the embryo, the fragmentation of the planetesimals, the velocity evolution of all involved bodies, as well as the viscous spreading of the filament. We find that the embryo accretes all available material in the filament during the lifetime of the protoplanetary disc only in the inner regions of the disc. In contrast, we find little or no growth in the outer parts of the disc beyond 5–10 AU. Overall, our results demonstrate very long timescales for collisional growth of planetesimals in the regions of the protoplanetary

disc where giant planets form. As such, in order to form giant planets in cold orbits, pebble accretion must act directly on the largest bodies present in the initial mass-function of planetesimals with little or no help from mutual collisions.

27. Magnetic field properties in star formation: a review of their analysis methods and interpretation

Junhao Liu, Qizhou Zhang, Keping Qiu ★ Linearly polarized emission from dust grains and molecular spectroscopy is an effective probe of the magnetic field topology in the interstellar medium and molecular clouds. The longstanding Davis-Chandrasekhar-Fermi (DCF) method and the recently developed Histogram of Relative Orientations (HRO) analysis and the polarization-intensity gradient (KTH) method are widely used to assess the dynamic role of magnetic fields in star formation based on the plane-of-sky component of field orientations inferred from the observations. We review the advances and limitations of these methods and summarize their applications to observations. Numerical tests of the DCF method, including its various variants, indicate that its largest uncertainty may come from the assumption of energy equipartition, which should be further calibrated with simulations and observations. We suggest that the ordered and turbulent magnetic fields of particular observations are local properties of the considered region. An analysis of the polarization observations using DCF estimations suggests that magnetically trans-to-super-critical and averagely trans-to-super-Alfvénic clumps/cores form in sub-critical clouds. High-mass star-forming regions may be more gravity-dominant than their low-mass counterparts due to higher column density. The observational HRO studies clearly reveal that the preferential relative orientation between the magnetic field and density structures changes from parallel to perpendicular with increasing column densities, which, in conjunction with simulations, suggests that star formation is ongoing in trans-to-sub-Alfvénic clouds. There is a possible transition back from perpendicular to random alignment at higher column densities. Results from observational studies using the KTH method broadly agree with those of the HRO and DCF studies.

28. A Census of the 32 Ori Association with Gaia

K. L. Luhman ★ I have used high-precision photometry and astrometry from the third data release of Gaia (DR3) to identify candidate members of the 32 Ori association. Spectral types and radial velocities have been measured for subsets of the candidates using new and archival spectra. For the candidates that have radial velocity measurements, I have used UVW velocities to further constrain their membership, arriving at a final catalog of 169 candidates. I estimate that the completeness of the survey is 90% for spectral types of <=M7 (>=0.06 Msun). The histogram of spectral types for the 32 Ori candidates exhibits a maximum at M5 (0.15 Msun), resembling the distributions measured for other young clusters and associations in the solar neighborhood. The available UVW velocities indicate that the association is expanding, but they do not produce a well-defined kinematic age. Based on their sequences of low-mass stars in color-magnitude diagrams, the 32 Ori association and Upper Centaurus-Lupus/Lower Centaurus-Crux (UCL/LCC) are coeval to within +/-1.2 Myr, and they are younger than the Beta Pic moving group by 3 Myr, which agrees with results from previous analysis based on the second data release of Gaia. Finally, I have used mid-infrared (IR) photometry from the Wide-field Infrared Survey Explorer to check for excess emission from circumstellar disks among the 32 Ori candidates. Disks are detected for 18 candidates, half of which are reported for the first time in this work. The fraction of candidates at <=M6 that have full, transitional, or evolved disks is 10/149=0.07+0.03/-0.02, which is consistent with the value for UCL/LCC.

29. A Novel Survey for Young Substellar Objects with the W band Filter.V. IC 348 and Barnard 5 in the Perseus Cloud

Bhavana Lalchand, Wen-Ping Chen, Beth A. Biller, Loic Albert, Katelyn Allers, Sophie Dubber, Zhoujian Zhang, Michael C. Liu, Jessy Jose, Belinda Damian, Tanvi Sharma, Mickael Bonnefoy, Yumiko Oasa ★ We report the discovery of substellar objects in the young star cluster IC 348 and the neighboring Barnard 5 dark cloud, both at the eastern end of the Perseus star-forming complex. The substellar candidates are selected using narrowband imaging, i.e., on and off photometric technique with a filter centered around the water absorption feature at 1.45 microns, a technique proven to be efficient in detecting water-bearing substellar objects. Our spectroscopic observations confirm three brown dwarfs in IC 348. In addition, the source WBIS 03492858+3258064, reported in this work, is the first confirmed brown dwarf discovered toward Barnard 5. Together with the young stellar population selected via near- and mid-infrared colors using the Two Micron All Sky Survey and the Wide-field Infrared Survey Explorer, we diagnose the relation between stellar versus substellar objects with the associated molecular clouds. Analyzed by Gaia EDR3 parallaxes and kinematics of the cloud members across the Perseus region, we propose the star formation scenario of the complex under influence of the nearby OB association.

30. Millimeter Gap Contrast as a Probe for Turbulence Level in Protoplanetary Disks

Yao Liu, Gesa H. -M. Bertrang, Mario Flock, Giovanni P. Rosotti, Ewine F. van Dishoeck, Yann Boehler, Stefano Facchini, Can Cui, Sebastian Wolf, Min Fang ★ Turbulent motions are believed to regulate angular momentum transport and influence dust evolution in protoplanetary disks. Measuring the strength of turbulence is challenging through gas line observations because of the requirement for high spatial and spectral resolution data, and an exquisite determination of the temperature. In this work, taking the well-known HD 163296 disk as an example, we investigated the contrast of gaps identified in high angular resolution continuum images as a probe for the level of turbulence. With self-consistent radiative transfer models, we simultaneously analyzed the radial brightness profiles along the disk major and minor axes, and the azimuthal brightness profiles of the B67 and B100 rings. By fitting all the gap contrasts measured from these profiles, we constrained the gas-to-dust scale height ratio Λ to be $3.0^{+0.3}_{-0.8}$, $1.2^{+0.1}_{-0.1}$ and ≥ 6.5 for the D48, B67 and B100 regions, respectively. The varying gas-to-dust scale height ratios indicate that the degree of dust settling changes with radius. The inferred values for Λ translate into a turbulence level of $\alpha_{\rm turb} < 3 \times 10^{-3}$ in the D48 and B100 regions, which is consistent with previous upper limits set by gas line observations. However, turbulent motions in the B67 ring are strong with $\alpha_{\rm turb} \sim 1.2 \times 10^{-2}$. Due to the degeneracy between Λ and the depth of dust surface density drops, the turbulence strength in the D86 gap region is not constrained.

31. Stratified Distribution of Organic Molecules at the Planet-Formation Scale in the HH 212 Disk Atmosphere

Chin-Fei Lee, Claudio Codella, Cecilia Ceccarelli, Ana Lopez-Sepulcre ★ Formamide (NH2CHO) is considered an important prebiotic molecule because of its potential to form peptide bonds. It was recently detected in the atmosphere of the HH 212 protostellar disk on the Solar-System scale where planets will form. Here we have mapped it and its potential parent molecules HNCO and H2CO, along with other molecules CH3OH and CH3CHO, in the disk atmosphere, studying its formation mechanism. Interestingly, we find a stratified distribution of these molecules, with the outer emission radius increasing from 24 au for NH2CHO and HNCO, to 36 au for CH3CHO, to 40 au for CH3OH, and then to 48 au for H2CO. More importantly, we find that the increasing order of the outer emission radius of NH2CHO, CH3OH, and H2CO is consistent with the decreasing order of their binding energies, supporting that they are thermally desorbed from the ice mantle on dust grains. We also find that HNCO, which has much lower binding energy than NH2CHO, has almost the same spatial distribution, kinematics, and temperature as NH2CHO, and is thus more likely a daughter species of desorbed NH2CHO. On the other hand, we find that H2CO has a more extended spatial distribution with different kinematics from NH2CHO, thus questioning whether it can be the gas-phase parent molecule of NH2CHO.

32. The evolution of protoplanetary disc radii and disc masses in star-forming regions

Bridget Marchington, Richard J. Parker ★ Protoplanetary discs are crucial to understanding how planets form and evolve, but these objects are subject to the vagaries of the birth environments of their host stars. In particular, photoionising radiation from massive stars has been shown to be an effective agent in disrupting protoplanetary discs. External photoevaporation leads to the inward evolution of the radii of discs, whereas the internal viscous evolution of the disc causes the radii to evolve outwards. We couple N-body simulations of star-forming regions with a post-processing analysis of disc evolution to determine how the radius and mass distributions of protoplanetary discs evolve in young star-forming regions. To be consistent with observations, we find that the initial disc radii must be of order 100au, even though these discs are readily destroyed by photoevaporation from massive stars. Furthermore, the observed disc radii distribution in the Orion Nebula Cluster is more consistent with moderate initial stellar densities ($100 M_\odot$ pc^{-3}), in tension with dynamical models that posit much higher inital densities for the ONC. Furthermore, we cannot reproduce the observed disc radius distribution in the Lupus star-forming region if its discs are subject to external photoevaporation. A more detailed comparison is not possible due to the well-documented uncertainties in determining the ages of pre-main sequence (disc-hosting) stars.

33. The physical and chemical structure of Sagittarius B2 – VI. UCHII regions in Sgr B2

Fanyi Meng, Álvaro Sánchez-Monge, Peter Schilke, Adam Ginsburg, Chris De Pree, Nazar Budaiev, Desmond Jeff, Anika Schmiedeke, Andreas Schwörer, V. S. Veena, Thomas Möller ★ The giant molecular cloud Sagittarius B2 (hereafter SgrB2) is the most massive region with ongoing high-mass star formation in the Galaxy. Two ultra-compact HII (UCHII) regions were identified in SgrB2's central hot cores, SgrB2(M) and SgrB2(N). Our aim is to characterize the properties of the HII regions in the entire SgrB2 cloud. Comparing the HII regions and the dust cores, we aim to depict the evolutionary stages of different parts of SgrB2. We use the Very Large Array in its A, CnB, and D configurations, and in the frequency band C (6 GHz) to observe the whole SgrB2 complex. Using ancillary VLA data at 22.4 GHz and ALMA data at 96 GHz, we calculated the physical parameters of the UCHII regions and their dense gas environment. We identify 54 UCHII regions in the 6 GHz image, 39 of which are also detected at 22.4 GHz. Eight of the 54 UCHII regions are newly discovered. The UCHII regions have radii between 0.006pc and 0.04pc, and have emission measure between 10^6pc cm^{-6} and 10^9pc cm^{-6}. The UCHII regions are ionized by stars of types from B0.5 to O6. We found a typical gas density of $\sim 10^6 - 10^9$cm^{-3} around the UCHII regions. The pressure of the UCHII regions and the dense gas surrounding them are comparable. The expansion timescale of

these UCHII regions is determined to be $\sim 10^4 - 10^5$yr. The percentage of the dust cores that are associated with HII regions are 33%, 73%, 4%, and 1% for SgrB2(N), SgrB2(M), SgrB2(S), and SgrB2(DS), respectively. Two-thirds of the dust cores in SgrB2(DS) are associated with outflows. The electron densities of the UCHII regions we identified are in agreement with that of typical UCHII regions, while the radii are smaller than those of the typical UCHII regions. The dust cores in SgrB2(N) are more evolved than in SgrB2(DS) but younger than in SgrB2(M).

34. The Molecular Composition of Shadowed Protosolar Disk Midplanes beyond the Water Snowline

Shota Notsu, Kazumasa Ohno, Takahiro Ueda, Catherine Walsh, Christian Eistrup, Hideko Nomura ★ The disk midplane temperature is potentially affected by the dust traps/rings. The dust depletion beyond the water snowline will cast a shadow. In this study, we adopt a detailed gas-grain chemical reaction network, and investigate the radial gas and ice abundance distributions of dominant carbon-, oxygen-, and nitrogen-bearing molecules in disks with shadow structures beyond the water snowline around a protosolar-like star. In shadowed disks, the dust grains at around $3 - 8$ au are predicted to have more than around $5 - 10$ times amounts of ices of organic molecules such as H_2CO, CH_3OH, and NH_2CHO, saturated hydrocarbon ices such as CH_4 and C_2H_6, in addition to H_2O, CO, CO_2, NH_3, N_2, and HCN ices, compared with those in non-shadowed disks. In the shadowed regions, we find that hydrogenation (especially of CO ice) is the dominant formation mechanism of complex organic molecules. The gas-phase N/O ratios show much larger spatial variations than the gas-phase C/O ratios, thus the N/O ratio is predicted to be a useful tracer of the shadowed region. N_2H^+ line emission is a potential tracer of the shadowed region. We conclude that a shadowed region allows the recondensation of key volatiles onto dust grains, provides a region of chemical enrichment of ices that is much closer to the star than within a non-shadowed disk, and may explain to some degree the trapping of O_2 ice in dust grains that formed comet 67P/Churyumov-Gerasimenko. We discuss that, if formed in a shadowed disk, Jupiter does not need to have migrated vast distances.

35. N-bearing complex organics toward high-mass protostars: Constant ratios pointing to formation in similar pre-stellar conditions across a large mass range

P. Nazari, J. D. Meijerhof, M. L. van Gelder, A. Ahmadi, E. F. van Dishoeck, B. Tabone, D. Langeroodi, N. F. W. Ligterink, J. Jaspers, M. T. Beltrán, G. A. Fuller, Á. Sánchez-Monge, P. Schilke ★ No statistical study of COMs toward a large sample of high-mass protostars with ALMA has been carried out so far. We aim to study six N-bearing species: CH_3CN, HNCO, NH_2CHO, C_2H_5CN, C_2H_3CN and CH_3NH_2 in a large sample of high-mass protostars. From the ALMAGAL survey, 37 of the most line-rich hot molecular cores are selected. Next, we fit their spectra and find column densities and excitation temperatures of the above N-bearing species, in addition to CH_3OH. We (tentatively) detect CH_3NH_2 in $\sim 32\%$ of the sources. We find three groups of species when comparing their excitation temperatures: hot (NH_2CHO; Tex $>$ 250 K), warm (C_2H_3CN, $HN^{13}CO$ and $CH_3^{13}CN$; 100 K $<$ Tex $<$ 250 K) and cold species (CH_3OH and CH_3NH_2; Tex $<$ 100 K). This temperature segregation reflects the trend seen in their sublimation temperatures and validates the idea of onion-like structure of COMs around protostars. Moreover, the molecules studied here show constant column density ratios across low- and high-mass protostars with scatter less than a factor ~ 3 around the mean. The constant column density ratios point to a common formation environment of COMs or their precursors, most likely in the pre-stellar ices. The scatter around the mean of the ratios, although small, varies depending on the species considered. This spread can either have a physical origin (source structure, line or dust optical depth) or a chemical one. Formamide is most prone to the physical effects as it is tracing the closest regions to the protostars, whereas such effects are small for other species. Assuming that all molecules form in the pre-stellar ices, the scatter variations could be explained by differences in lifetimes or physical conditions of the pre-stellar clouds. If the pre-stellar lifetimes are the main factor, they should be similar for low- and high-mass protostars.

36. Circumplanetary disk ices. I. Ice formation vs. viscous evolution and grain drift

Nickolas Oberg, Inga Kamp, Stephanie Cazaux, Peter Woitke, Wing-Fai Thi ★ The large icy moons of Jupiter formed in a circumplanetary disk (CPD). CPDs are fed by infalling circumstellar gas and dust which may be shock-heated upon accretion or sublimated while passing through an optically thin gap. Accreted material is then either incorporated into moons, falls into the planet, or is lost beyond the disk edge on relatively short timescales. If ices are sublimated during accretion onto the CPD we know there must be sufficient time for them to recondense or moons such as Ganymede or Callisto could not form. The chemical timescale to form sufficiently icy solids places a novel constraint on the dynamical behaviour and properties of CPDs. We use the radiation thermochemical code ProDiMo to analyze how the radial ice abundance evolves in CPDs. We consider different initial chemical conditions of the disk to explore the consequences of infalling material being inherited from the circumstellar disk or being reset to atomic conditions by shock-heating. We contrast the timescales of ice formation with those of viscous evolution and radial dust drift. Water ice can form very efficiently in the CPD from initially atomic conditions, as a significant fraction is efficiently re-deposited on dust grains within $<$ 1 yr. Radial grain drift timescales are in general longer than those of ice formation on grains. Icy grains of size $a < 3$ mm retain their icy mantles while crossing an optically thin circumstellar disk gap at 5 au for $L_* < 10$ $L_\odot$. Three-body reactions play an important role in water formation in the

dense midplane condition of CPDs. The CPD midplane must be depleted in dust relative to the circumstellar disk by a factor 10-50 to produce solids with the ice to rock ratio of the icy Galilean satellites. The CPD snowline is not erased by radial grain drift, which is consistent with the compositional gradient of the Galilean satellites being primordial.

37. Tracers of Dense Gas in the Outer Galaxy

Sudeshna Patra, Neal J. Evans II, Kee-Tae Kim, Mark Heyer, Jens Kauffmann, Jessy Jose, Manash R. Samal, Swagat R. Das ★ We have mapped HCN and HCO^+ (J = 1 → 0) line emission toward a sample of seven star-forming regions (with 12 + log[O/H] range from 8.34 to 8.69) in the outer Milky Way (Galactocentric distance > 9.5 kpc), using the 14-meter radio telescope of the Taeduk Radio Astronomy Observatory (TRAO). We compare these two molecular lines with other conventional tracers of dense gas, millimeter-wave continuum emission from dust and extinction thresholds ($A_V \geq 8$ mag), inferred from the ^{13}CO line data. HCN and HCO^+ correlate better with the millimeter emission than with the extinction criterion. A significant amount of luminosity comes from regions below the extinction criterion and outside the millimeter clump for all the clouds. The average fraction of HCN luminosity from within the regions with $A_V \geq 8$ mag is 0.343 ± 0.225; for the regions of millimeter emission, it is 0.478 ± 0.149. Based on a comparison with column density maps from Herschel, HCN and HCO^+ trace dense gas in high column density regions better than does ^{13}CO. HCO^+ is less concentrated than HCN for outer Galaxy targets, in contrast with the inner Galaxy sample, suggesting that metallicity may affect the interpretation of tracers of dense gas. The conversion factor between the dense gas mass (M_{dense}) and line luminosities of HCN and HCO^+, when integrated over the whole cloud, is comparable with factors used in extragalactic studies.

38. Studying a precessing jet of a massive young stellar object within a chemically rich region

S. Paron, D. Mast, C. Fariña, M. B. Areal, M. E. Ortega, N. C. Martinez, M. Celis Peña ★ In addition to the large surveys and catalogs of massive young stellar objects and outflows, dedicated studies of particular sources, in which high-angular observations (mainly at near-IR and mm) are analyzed in depth, are needed to shed light on the processes involved in the formation of massive stars. The galactic source G079.1272+02.2782 (G79), a MYSO at about 1.4 kpc, is an ideal source to carry out this kind of studies. Near-IR integral field spectroscopic observations were carried out using NIFS at Gemini-North. The spectral and angular resolutions, allow us to perform a detailed study of the source and its southern jet, resolving structures with sizes between 200 and 300 au. As a complement, millimeter data retrieved from the JCMT and the IRAM 30m telescope databases were analyzed to study the molecular gas at a larger spatial scale. The analysis of a jet extending southwards shows cork-screw like structures at 2.2 um continuum, strongly suggesting that the jet is precessing. The jet velocity is estimated in 30-43 km/s and it is coming to us along the line of sight. We suggest that the precession may be produced by the gravitational tidal effects generated in a probable binary system, and we estimate a jet precession period of about 10^3 yr, indicating a slow-precessing jet, which is in agreement with the observed helical features. An analysis of H2 lines along the jet allows us to investigate in detail a bow-shock produced by this jet. We find that this bow-shock is indeed generated by a C-type shock and it is observed coming to us, with some inclination angle, along the line of sight. This is confirmed by the analysis of molecular outflows at a larger spatial scale. A brief analysis of several molecular species at millimeter wavelengths indicates a complex chemistry developing at the external layers of the molecular clump in which MYSO G79 is embedded.

39. Towards a comprehensive view of accretion, inner disks, and extinction in classical T Tauri stars: an ODYSSEUS study of the Orion OB1b association

Caeley V. Pittman, Catherine C. Espaillat, Connor E. Robinson, Thanawuth Thanathibodee, Nuria Calvet, John Wendeborn, Jesus Hernández, Carlo F. Manara, Fred Walter, Péter Ábrahám, Juan M. Alcalá, Sílvia H. P. Alencar, Nicole Arulanantham, Sylvie Cabrit, Jochen Eislöffel, Eleonora Fiorellino, Kevin France, Manuele Gangi, Konstantin Grankin, Gregory J. Herczeg, Ágnes Kóspál, Ignacio Mendigutía, Javier Serna, Laura Venuti ★ The coevolution of T Tauri stars and their surrounding protoplanetary disks dictates the timescales of planet formation. In this paper, we present magnetospheric accretion and inner disk wall model fits to NUV-NIR spectra of nine classical T Tauri stars in Orion OB1b as part of the Outflows and Disks around Young Stars: Synergies for the Exploration of ULLYSES Spectra (ODYSSEUS) Survey. Using NUV-optical spectra from the Hubble UV Legacy Library of Young Stars as Essential Standards (ULLYSES) Director's Discretionary Program and optical-NIR spectra from the PENELLOPE VLT Large Programme, we find that the accretion rates of these targets are relatively high for the region's intermediate age of 5.0 Myr; rates range from $0.5 - 17.2 \times 10^{-8}$ $M_\odot$/yr, with a median value of 1.2×10^{-8} $M_\odot$/yr. The NIR excesses can be fit with 1200-1800 K inner disk walls located at 0.05-0.10 AU from the host stars. We discuss the significance of the choice in extinction law, as the measured accretion rate depends strongly on the adopted extinction value. This analysis will be extended to the complete sample of T Tauri stars being observed through ULLYSES to characterize accretion and inner disks in star-forming regions of different ages and stellar populations.

40. Towards a comprehensive view of accretion, inner disks, and extinction in classical T Tauri stars: an ODYSSEUS study of the Orion OB1b association

Caeley V. Pittman, Catherine C. Espaillat, Connor E. Robinson, Thanawuth Thanathibodee, Nuria Calvet, John Wendeborn, Jesus Hernández, Carlo F. Manara, Fred Walter, Péter Ábrahám, Juan M. Alcalá, Sílvia H. P. Alencar, Nicole Arulanantham, Sylvie Cabrit, Jochen Eislöffel, Eleonora Fiorellino, Kevin France, Manuele Gangi, Konstantin Grankin, Gregory J. Herczeg, Ágnes Kóspál, Ignacio Mendigutía, Javier Serna, Laura Venuti ★ The coevolution of T Tauri stars and their surrounding protoplanetary disks dictates the timescales of planet formation. In this paper, we present magnetospheric accretion and inner disk wall model fits to NUV-NIR spectra of nine classical T Tauri stars in Orion OB1b as part of the Outflows and Disks around Young Stars: Synergies for the Exploration of ULLYSES Spectra (ODYSSEUS) Survey. Using NUV-optical spectra from the Hubble UV Legacy Library of Young Stars as Essential Standards (ULLYSES) Director's Discretionary Program and optical-NIR spectra from the PENELLOPE VLT Large Programme, we find that the accretion rates of these targets are relatively high for the region's intermediate age of 5.0 Myr; rates range from $0.5 - 17.2 \times 10^{-8}$ $M_{\odot}$/yr, with a median value of 1.2×10^{-8} $M_{\odot}$/yr. The NIR excesses can be fit with 1200-1800 K inner disk walls located at 0.05-0.10 AU from the host stars. We discuss the significance of the choice in extinction law, as the measured accretion rate depends strongly on the adopted extinction value. This analysis will be extended to the complete sample of T Tauri stars being observed through ULLYSES to characterize accretion and inner disks in star-forming regions of different ages and stellar populations.

41. X-ray flares of the young planet host DS Tuc A

I. Pillitteri, C. Argiroffi, A. Maggio, G. Micela, S. Benatti, F. Reale, S. Colombo, S. J. Wolk ★ Abridged. We observed the 40 Myr old star DS Tuc A with XMM-Newton and recorded two X-ray bright flares, with the second event occurring about 12 ks after the first one. Their duration from the rise to the end of the decay was of about 8-10 ks in soft X-rays (0.3-10 keV). The flares were also recorded in the band 200-300 nm with the UVM2 filter of the Optical Monitor. The duration of the flares in UV was about 3 ks. The observed delay between the peak in the UV band and in X-rays is a probe of the heating phase followed by the evaporation and increase of density and emission measure of the flaring loop. The coronal plasma temperature at the two flare peaks reached 54-55 MK. The diagnostics based on temperatures and time scales of the flares applied to these two events allow us to infer a loop length of 5-7 x 10^{1}0 cm, which is about the size of the stellar radius. We also infer values of electron density at the flare peaks of 2.3-6.5 x 10^{1}1 cm^{-}3 , and a minimum magnetic field strength of order of 300-500 G needed to confine the plasma. The energy released during the flares was of order of 5-8 x 10^{3}4 erg in the band 0.3-10 keV and 0.9-2.7 x 10^{3}3 erg in the UV band (200-300 nm). We speculate that the flares were associated with Coronal Mass Ejections (CMEs) that hit the planet about 3.3 hr after the flares and dramatically increasing the rate of evaporation of the planet. From the RGS spectra we retrieved the emission measure distribution and the abundances of coronal metals during the quiescent and the flaring states. In agreement with what inferred from time resolved spectroscopy and EPIC spectra, also from the analysis of RGS spectra during the flares we infer a high electron density.

42. Deep Near-Infrared Survey Toward the W40 and Serpens South Region in Aquila Rift: A Comprehensive Catalog of Young Stellar Objects

Jia Sun, Robert A. Gutermuth, Hongchi Wang, Miaomiao Zhang, Shuinai Zhang, Yuehui Ma, Xinyu Du, Min Long ★ Active star forming regions are excellent laboratories for studying the origins and evolution of young stellar object (YSO) clustering. The W40 - Serpens South region is such a region, and we compile a super near-and-mid-infrared catalog of point sources in it, based on deep NIR observations of CFHT in combination with 2MASS, UKIDSS, and Spitzer catalogs. From this catalog, we identify 832 YSOs, and classify 15, 135, 647, and 35 of them to be the deeply embedded sources, Class I, Class II YSOs, and transition disk sources, respectively. In general, these YSOs are well correlated with the filamentary structures of molecular clouds, especially the deeply embedded sources and the Class I YSOs. The W40 central region is dominated by Class II YSOs, but in the Serpens South region, a half of the YSOs are Class I. We further generate a minimum spanning tree (MST) for all the YSOs. Around the W40 cluster, there are eight prominent MST branches that may trace vestigial molecular gas filaments that once fed gas to the central natal gas clump. Of the eight, only two now include detectable filamentary gas in Herschel data and corresponding Class I YSOs, while the other six are exclusively populated with Class II. Four MST branches overlap with the Serpens South main filament, and where they intersect, molecular gas "hubs" and more Class I YSOs are found. Our results imply a mixture of YSO distributions composed of both primordial and somewhat evolved YSOs in this star forming region.

43. Hierarchical Structure of YSO Clusters in the W40 and Serpens South Region: Group Extraction and Comparison with Fractal Clusters

Jia Sun, Robert A. Gutermuth, Hongchi Wang, Shuinai Zhang, Min Long ★ Young stellar clusters are believed to inherit the spatial distribution like hierarchical structures of their natal molecular cloud during their formation. However, the change of the structures between the cloud and the young clusters is not well constrained observationally. We select the W40 -

Serpens South region (7×9 pc^2) of the Aquila Rift as a testbed and investigate hierarchical properties of spatial distribution of young stellar objects (YSOs) in this region. We develop a minimum spanning tree (MST)-based method to group stars into several levels by successively cutting down edges longer than an algorithmically determined critical value. A total of 832 YSOs are divided into 5 levels with 23 groups. For describing the hierarchical properties in a controlled way, we construct a set of synthetic source distributions at various fractal dimensions, and apply the same method to explore their group characters. By comparing the Q parameter and the surface density profiles of the observed and the synthetic data, we find that the YSO observation matches spatial patterns from multi-fractal dimensions. In the periphery region where the molecular clouds are more diffuse, the YSO structure is close to a fractal dimension of 2.0, while in the core regions the fractal dimensions are close to 1.6 and 1.4 for the W40 and the Serpens South regions, respectively. Therefore, the YSOs may inherit the fractal pattern of the dense part of the molecular clouds, but such pattern dissipates slowly in several Myr.

44. Tracking the ice mantle history in the Solar-type Protostars of NGC 1333 IRAS 4

Marta De Simone, Cecilia Ceccarelli, Claudio Codella, Brian E. Svoboda, Claire J. Chandler, Mathilde Bouvier, Satoshi Yamamoto, Nami Sakai, Yao-Lun Yang, Paola Caselli, Bertrand Lefloch, Hauyu Baobab Liu, Ana López-Sepulcre, Laurent Loinard, Jaime E. Pineda, Leonardo Testi ★ To understand the origin of the diversity observed in exoplanetary systems, it is crucial to characterize the early stages of their formation, represented by Solar-type protostars. Likely, the gaseous chemical content of these objects directly depends on the composition of the dust grain mantles formed before the collapse. Directly retrieving the ice mantle composition is challenging, but it can be done indirectly by observing the major components, such as NH3 and CH3OH at cm wavelengths, once they are released into the gas-phase during the warm protostellar stage. We observed several CH3OH and NH3 lines toward three Class 0 protostars in NGC1333 (IRAS 4A1, IRAS 4A2, and IRAS 4B), at high angular resolution (1"; 300 au) with the VLA interferometer at 24-26 GHz. Using a non-LTE LVG analysis, we derived a similar NH3/CH3OH abundance ratio in the three protostars (<0.5, 0.015-0.5, and 0.003-0.3 for IRAS 4A1, 4A2, and 4B, respectively). Hence, we infer they were born from pre-collapse material with similar physical conditions. Comparing the observed abundance ratios with astrochemical model predictions, we constrained the dust temperature at the time of the mantle formation to be 17 K, which coincides with the average temperature of the southern NGC 1333 diffuse cloud. We suggest that a brutal event started the collapse that eventually formed IRAS 4A1, 4A2 and 4B, which,therefore, did not experience the usual pre-stellar core phase. This event could be the clash of a bubble with NGC 1333 south, that has previously been evoked in the literature.

45. HST UV Spectroscopy of the Planet-Hosting T Tauri Star PDS 70

Stephen L. Skinner, Marc Audard ★ We summarize Hubble Space Telescope (HST) UV observations of the weak-lined T Tauri star (wTTS) PDS 70 obtained with the Space Telescope Imaging Spectrograph (STIS). These observations provide the first far-UV (FUV) and near-UV (NUV) spectra of PDS 70. Ground-based observations have so far revealed two formative giant planets orbiting in a wide gap in its circumstellar disk. Both the star and young planets are thought to still be accreting. The HST spectra provide new insight into physical conditions in the star's outer atmosphere and circumstellar environment. The spectra are dominated by chromospheric and transition region emission lines with maximum formation temperatures log T = 4.5 - 5.2 K. Stellar continuum emission is present in the NUV but we find no significant FUV continuum, as could arise from accretion shocks. Several fluorescent FUV H2 emission lines are present, a surprising result since H2 lines are usually undetected in wTTS. The H2 lines likely originate in irradiated circumstellar gas that could serve as a reservoir for the star's waning accretion. A previously established correlation between C IV line luminosity and accretion rate yields $\dot{M}_{acc} \sim 10^{-10}$ $M_\odot$ yr^{-1}, consistent with previous estimates. ALMA disk gas models imply strong absorption of stellar X-ray and UV (XUV) radiation near the star, effectively shielding the planets. Inner disk gas is exposed to ongoing photoevaporation by XUV radiation and the disk is nearing the end of its expected lifetime, making PDS 70 an important example of a young planet-hosting star in the late stage of accretion.

46. An unusual reservoir of water emission in the VV CrA A protoplanetary disk

Colette Salyk, Klaus M. Pontoppidan, Andrea Banzatti, Ulrich Käufl, Cassandra Hall, Ilaria Pascucci, Andrés Carmona, Geoffrey A. Blake, Richard Alexander, Inga Kamp ★ We present an analysis of an unusual pattern of water vapor emission from the ∼2 Myr-old low-mass binary system VV CrA, as observed in infrared spectra obtained with VLT-CRIRES, VLT-VISIR, and Spitzer-IRS. Each component of the binary shows emission from water vapor in both the L ($\sim 3\,\mu$m) and N ($\sim 12\,\mu$m) bands. The N-band and Spitzer spectra are similar to those previously observed from young stars with disks, and are consistent with emission from an extended protoplanetary disk. Conversely, the CRIRES L-band data of VV CrA A show an unusual spectrum, which requires the presence of a water reservoir with high temperature ($T \gtrsim 1500$ K), column density ($N_{\rm H2O} \sim 3 \times 10^{20}$ cm^{-2}), and turbulent broadening ($v \sim 10$ km s^{-1}), but very small emitting area ($A \lesssim 0.005$ AU^2). Similarity with previously observed water emission from V1331 Cyg (Doppmann et al. 2011) and SVS 13 (Carr et al. 2004) suggests that the presence of such a reservoir may be linked to evolutionary state, perhaps related to the presence of high accretion rates or winds. While the inner disk may harbor such a reservoir, simple Keplerian models do not match well with

emitting line shapes, and alternative velocity fields must be considered. We also present a new idea, that the unusual emission could arise in a circumplanetary disk, embedded within the larger VV CrA A protoplanetary disk. Additional data are likely required to determine the true physical origin of this unusual spectral pattern.

47. Mapping the Complex Kinematic Substructure in the TW Hya Disk

Richard Teague, Jaehan Bae, Sean M. Andrews, Myriam Benisty, Edwin A. Bergin, Stefano Facchini, Jane Huang, Cristiano Longarini, David Wilner ★ We present ALMA observations of CO $J = 2-1$ and CS $J = 5-4$ emission from the disk around TW Hydrae. Both molecules trace a predominantly Keplerian velocity structure, although a slowing of the rotation velocity is detected at the outer edge of the disk beyond $\approx$ 140 au in CO emission. This was attributed to the enhanced pressure support from the gas density taper near the outer edge of the disk. Subtraction of an azimuthally symmetric background velocity structure reveals localized deviations in the gas kinematics traced by each of the molecules. Both CO and CS exhibit a 'Doppler flip' feature, centered nearly along the minor axis of the disk (PA $\sim$ 60 degrees) at a radius of , coinciding with the large gap observed in scattered light and mm continuum. In addition, the CO emission, both through changes in intensity and its kinematics, traces a tightly wound spiral, previously seen with higher frequency CO $J = 3-2$ observations (Teague et al., 2019). Through comparison with linear models of the spiral wakes generated by embedded planets, we interpret these features in the context of interactions with a Saturn-mass planet within the gap at a position angle of PA = 60 degrees, consistent with the theoretical predictions of (Mentiplay et al. 2019). The lack of a corresponding spiral in the CS emission is attributed to the strong vertical dependence on the buoyancy spirals which are believed to only grow in the atmospheric of the disk, rather than those traced by CS emission.

48. Characterizing the 3D Kinematics of Young Stars in the Radcliffe Wave

Alan J. Tu, Catherine Zucker, Joshua S. Speagle, Angus Beane, Alyssa Goodman, João Alves, Jacqueline Faherty, Andreas Burkert ★ We present an analysis of the kinematics of the Radcliffe Wave, a 2.7-kpc-long sinusoidal band of molecular clouds in the solar neighborhood recently detected via 3D dust mapping. With Gaia DR2 astrometry and spectroscopy, we analyze the 3D space velocities of $\sim$ 1500 young stars along the Radcliffe Wave in action-angle space, using the motion of the wave's newly born stars as a proxy for its gas motion. We find that the vertical angle of young stars – corresponding to their orbital phase perpendicular to the Galactic plane – varies significantly as a function of position along the structure, in a pattern potentially consistent with a wave-like oscillation. This kind of oscillation is not seen in a control sample of older stars from Gaia occupying the same volume, disfavouring formation channels caused by long-lived physical processes. We use a "wavy midplane" model to try to account for the trend in vertical angles seen in young stars, and find that while the best-fit parameters for the wave's spatial period and amplitude are qualitatively consistent with the existing morphology defined by 3D dust, there is no evidence for additional velocity structure. These results support more recent and/or transitory processes in the formation of the Radcliffe Wave, which would primarily affect the motion of the wave's gaseous material. Comparisons of our results with new and upcoming simulations, in conjunction with new stellar radial velocity measurements in Gaia DR3, should allow us to further discriminate between various competing hypotheses.

49. Mid-Infrared and Maser Flux Variability Correlation in Massive Young Stellar Object G036.70+00.09

Mizuho Uchiyama, Kohei Ichikawa, Koichiro Sugiyama, Yoshihiro Tanabe, Yoshinori Yonekura ★ We present the discovery of the simultaneous flux variation of a massive young stellar object (MYSO) G036.70+00.09 (G036.70) both in the maser emission and mid-infrared (MIR;λ = 3–5 μm) bands. Utilizing the ALLWISE and NEOWISE archival databases covering a long time span of approximately 10 years with a cadence of 6 months, we confirmed that G036.70 indicates a stochastic year-long MIR variability with no signs of the WISE band color change of W1 (3.4 μm) $-$W2 (4.6 μm). Cross-matching the MIR data set with the high-cadence 6.7 GHz class II methanol maser flux using a Hitachi 32-m radio telescope that discovered its periodicity in the methanol maser of 53.0–53.2 days, we also determine the flux correlations between the two bands at two different timescales, year-long and day-long, both of which have never been reported in MYSOs except when they are in a state of the accretion burst phase. The results of our study support the scenario that a class II methanol maser is pumped up by infrared emission from accreting disks of MYSOs. We also discuss the possible origins of MIR and maser variability. To explain the two observed phenomena, a stochastic year-long MIR variability with no signs of significant color change and maser-MIR variability correlation, change in mass accretion rate and line-of-sight extinction because of nonaxisymmetric dust density distribution in a rotating accretion disk are possible origins. Observations through spectroscopic monitoring of accretion-related emission lines are essential for determining the origin of the observed variability in G036.70.

50. PRODIGE – Envelope to disk with NOEMA I. A 3000 au streamer feeding a Class I protostar

M. T. Valdivia-Mena, J. E. Pineda, D. M. Segura-Cox, P. Caselli, R. Neri, A. López-Sepulcre, N. Cunningham, L. Bouscasse, D. Semenov, Th. Henning, V. Piétu, E. Chapillon, A. Dutrey, A. Fuente, S. Guilloteau, T. H. Hsieh, I. Jiménez-Serra, S. Marino, M. J. Maureira, G. V. Smirnov-Pinchukov, M. Tafalla, B. Zhao ★ Context. In the past few years, there has been a rise in the detection of streamers, asymmetric flows of material directed toward the protostellar disk with material from outside the star's natal core. It is unclear how they affect the process of mass accretion, in particular beyond the Class 0 phase. Aims. We investigate the gas kinematics around Per-emb-50, a Class I source in the crowded star-forming region NGC 1333. Our goal is to study how the mass infall proceeds from envelope to disk scales in this source. Results. We discover a streamer delivering material toward Per-emb-50 in H_2CO and $C^{18}O$ emission. The streamer's emission can be well described by the analytic solutions for an infalling parcel of gas along a streamline with conserved angular momentum, both in the image plane and along the line of sight velocities. The streamer has a mean infall rate of 1.3×10^{-6} $M_\odot$ yr^{-1}, $5-10$ times higher than the current accretion rate of the protostar. SO and SO_2 emission reveal asymmetric infall motions in the inner envelope, additional to the streamer around Per-emb-50. Furthermore, the presence of SO_2 could mark the impact zone of the infalling material. Conclusions. The streamer delivers sufficient mass to sustain the protostellar accretion rate and might produce an accretion burst, which would explain the protostar's high luminosity with respect to other Class I sources. Our results highlight the importance of late infall for protostellar evolution: streamers might provide a significant amount of mass for stellar accretion after the Class 0 phase.

51. On the Relationship between CH_3OD Abundance and Temperature in the Orion KL Nebula

Olivia H. Wilkins, Geoffrey A. Blake ★ The relative abundances of singly-deuterated methanol isotopologues, $[CH_2DOH]/[CH_3OD]$, in star-forming regions deviate from the statistically expected ratio of 3. In Orion KL, the nearest high-mass star-forming region to Earth, the singly-deuterated methanol ratio is about 1, and the cause for this observation has been explored through theory for nearly three decades. We present high-angular resolution observations of Orion KL using the Atacama Large Millimeter/submillimeter Array to map small-scale changes in CH_3OD column density across the nebula, which provide a new avenue to examine the deuterium chemistry during star and planet formation. By considering how CH_3OD column densities vary with temperature, we find evidence of chemical processes that can significantly alter the observed column densities. The astronomical data are compared with existing theoretical work and support D-H exchange between CH_3OH and heavy water (i.e., HDO and D_2O) at methanol's hydroxyl site in the icy mantles of dust grains. The enhanced CH_3OD column densities are localized to the Hot Core-SW region, a pattern that may be linked to the coupled evolution of ice mantel chemistry and star formation in giant molecular clouds. This work provides new perspectives on deuterated methanol chemistry in Orion KL and informs considerations that may guide future theoretical, experimental, and observational work.

52. Kinematics and brightness temperatures of transition discs – A survey of gas substructures as seen with ALMA

Lisa Wölfer, Stefano Facchini, Nienke van der Marel, Ewine F. van Dishoeck, Myriam Benisty, Alexander J. Bohn, Logan Francis, Andrés F. Izquierdo, Richard D. Teague ★ In recent years, high-angular-resolution observations of the dust and gas in circumstellar discs have revealed a variety of morphologies, naturally triggering the question of whether these substructures are driven by forming planets. While it remains difficult to directly image embedded planets, a promising method to distinguish disc-shaping mechanisms is to study the gas kinematics as characterising deviations from Keplerian rotation can be used to probe underlying perturbations such as planets. Creating spiral structures, the latter can also be traced in the brightness temperature. Here we analyse the brightness temperatures and kinematics of a sample of 36 transition discs observed with ALMA to search for substructures possibly tracing companions. We use archival Band 6 and 7 observations of different CO isotopologues and fit Keplerian disc models to the velocity fields. After subtraction of an azimuthally averaged brightness temperature and Keplerian rotation model from the data, we find significant substructures in both residuals of eight sources. Other sources show tentative features, while half of our sample does not show any substructures that may be indicative of planet-disc interactions. For the first time, we compare the substructures from our analysis with various other indicators of planets. About 20spirals, possibly associated with the presence of planets, while the majority do not present as clear planet-driven signatures. Almost all discs that exhibit spirals in near-infrared scattered light show at least tentative features in the CO data. The present data are able to reveal only very massive bodies and a lack of features may suggest that, if there are planets, they are of lower mass (<1-3Mj) or located closer to the star within deep cavities. Dedicated observations and modelling efforts are needed to confirm such scenarios.

53. The Distribution of UV Radiation Field in the Molecular Clouds of Gould Belt

Jifeng Xia, Ningyu Tang, Qijun Zhi, Sihan Jiao, Jinjin Xie, Gary A. Fuller, Paul F. Goldsmith, Di Li ★ The distribution of ultraviolet (UV) radiation field provides critical constraints on the physical environments of molecular clouds. Within 1 kpc of our solar system and fostering protostars of different masses, the giant molecular clouds in the Gould Belt present an excellent opportunity to resolve the UV field structure in star forming regions. We performed spectral energy distribution (SED) fitting of the archival data from the Herschel Gould Belt Survey (HGBS). Dust radiative transfer analysis with the DUSTY code were applied to 23 regions in 14 molecular complexes of the Gould Belt, resulting in the spatial distribution of radiation field in these regions. For 10 of 15 regions with independent measurements of star formation rate, their star formation rate and UV radiation intensity largely conform to a linear correlation found in previous studies.