The Star Formation Newsletter

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The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star and planet formation and molecular clouds. You can submit material for the following sections: Abstracts of recently accepted papers (only for papers sent to refereed journals), Abstracts of recently accepted major reviews (not standard conference contributions), Dissertation Abstracts (presenting abstracts of new Ph.D dissertations), Meetings (announcing meetings broadly of interest to the star and planet formation and early solar system community), New Jobs (advertising jobs specifically aimed towards persons within the areas of the Newsletter), and Short Announcements (where you can inform or request information from the community). Additionally, the Newsletter brings short overview articles on objects of special interest, physical processes or theoretical results, the early solar system, as well as occasional interviews.

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Cover Picture

Barnard 59 is located at a distance of about 130 pc in the direction of the Galactic center. It is part of the larger cloud complex known as the Pipe Nebula, which is visible with the naked eye. B59 is the only part of the complex that is known to be forming stars, harboring several visible T Tauri stars and a number of deeply embedded sources detected by Spitzer and through submillimeter observations.

Image courtesy ESO.

Submitting your abstracts

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each Call for Abstracts. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/star-formation/index.cfm
Q: Your PhD in 1970 dealt with recombination lines of H, He, and C. How did you choose this subject?

A: My PhD thesis was on radio recombination line (RRL) emission from Galactic HII regions. At that time RRLs had only recently been detected and they presented the possibility to obtain a number of important physical properties of HII regions that were not so easily obtained by other observational probes. In particular, they are not attenuated by interstellar extinction and are limited only by the D$^{-2}$ dependence on distance. So most of the Galactic plane can be accessed by reasonable sized radio telescopes. Some of the properties that can be obtained included electron temperatures of the ionized gas, electron densities when stimulated emission and electron impact broadening are accounted for, the separation of turbulent and thermal line broadening, and the Helium-to-Hydrogen abundance ratios and their distributions around the ionizing star(s).

This was also an exciting time in radio astronomy because radio spectroscopy of emission from anything other than the HI 21cm line was quite exotic. This was especially true of RRLs since they originate from principal quantum levels of H, He, and C that are so weakly bound that such atoms can only exist in the vacuum of space. I was a summer student at the National Radio Astronomy Observatory (NRAO) in 1966 working with Dr. T. K. Menon on OH emission. I wanted to do a thesis in radio astronomy after that summer and contacted Dave Heeschen in 1967 about coming to NRAO to work with an NRAO scientist on a thesis project. He suggested that I contact Peter Mezger. Mezger and Högland had just detected the H109a line in 1965 and Peter was looking for a student to join his research group. I came to NRAO in 1968 from the University of Indiana. I began my thesis with Peter to use RRLs to derive physical properties of HII regions and to determine if HII regions showed a gradient in their properties as a function of galactocentric radius. Peter was a supportive and wise advisor from whom I learned a lot. After defending my thesis, Peter invited me to bring my Heinrich Hertz postdoctoral fellowship to MPIfR where he had recently accepted a directorship. I continued to collaborate with Peter until ~1973 or 1974 when our scientific interests began to diverge. About this time, Malcolm Walmsley and I found evidence (with considerable scatter) that the electron temperatures of HII regions tend to increase with galactocentric radius. We suggested that this was likely a result of decreasing ‘metal’ abundances (such as C, N, O, etc.) with galactocentric radius which act as coolants. More recent and sensitive studies have shown this to be the case.

Q: Back in 1979 Laques and Vidal discovered some mysterious nebulous objects in the Orion Nebula, which you subsequently studied.

A: Yes, Laques and Vidal had observed 6 compact sources at visible wavelengths in the Orion Nebula. With resolutions of 0.1′ to 0.2′, Marcello Felli, Doug Wood, Maria Massi and I (ApJ, 321, 516, 1987) found 22 (possibly 29) ‘solar system sized’ compact radio sources at a wavelength of 2 cm located within the central 90′×90′ of the Orion Nebula using the VLA. At this time, I believe this was the highest resolution and sensitivity radio image of Orion that existed. Guido Garay, Jim Moran, and Mark Reid had detected most of the same sources slightly earlier but with 2-3 times lower resolution and sensitivity. We proposed that these very compact objects were either dense molecular/dust globules that had been over-run by the expanding Orion Nebula which had formed thin, dense, ionized envelopes from exposure to UV radiation from the Trapezium stars; or, photo-ionized accretion disks of young, low-mass (∼1 M⊙) protostars, probably associated with the formation of the Trapezium. The high resolution of our image enabled us to narrow the possibilities to the two we proposed. Further study of these objects by O’Dell and co-workers have since shown (using even higher resolution images from Hubble) that the latter explanation is the correct one for many of the radio sources.

Q: In the late 1980’s you searched for and found numerous ammonia and water masers from UC HII regions.

A: Actually, before I left the Max Planck Institute for Radioastronomy in 1977, I had become interested in interstellar molecules, their chemistry and the physical properties that they could reveal about ‘dark clouds’ where stars are born. During the first half of the 1970s, I began collaborating with Gisbert Winnewisser and Malcolm Walmsley. Gisbert was an excellent laboratory molecular spectroscopist who taught me a lot about molecular spectroscopy and what a powerful tool it could be for the study of cold, dark, molecular clouds. Malcolm was an excellent theorist and observer. We observed the $1_{11}-1_{10}$ A
& E transitions (2 internal rotation transitions) of methyl formate at 18 cm with the 100 m Effelsberg telescope toward the Galactic center and postulated that formic acid might also be detectable since formic acid is closely related to methyl formate (remove the methyl group, CH₃, and replace it with H). We discovered formic acid in 1975 shortly after the methyl formate study. Throughout the 1980s, I was involved in numerous studies of molecular clouds to establish their distributions, masses, temperatures, column densities, etc. with my grad students and other collaborators. Some of my motivations were to try to understand the chemical networks that produced the range of molecules within some clouds. For example, we observed CN, HCN, HNC, HC$_3$N distributions relative to that of NH$_3$ to see if we could establish a reasonable idea of the formation sequence of these chemically related species. We learned a lot about the chemical diversity and relative abundances in molecular clouds, but I can’t say that we actually satisfactorily solved the chemical network for even chemically related species such as the N-bearing species noted above. My interest in masers (H$_2$O, NH$_3$, and OH) was motivated by their obvious association with star formation. H$_2$O, in particular, seems to be associated with massive star forming regions and generally has multiple components at a wide range in velocities. I had hoped that if we could understand the inversion process and the origin of the velocity components, they might provide details about the radiation field, hydrogen density, and the dynamics of the star formation process (rotating accretion disk, in-fall, outflows, and/or bipolar jets). I can’t say we made much progress from our maser studies in this area.

**Q:** Around the same time you also became interested in the infrared properties of dust cocoons surrounding newly formed O stars. What did you learn?

**A:** Interest in IR dust cocoons was ignited by the high spatial resolution VLA image survey of UC HII regions by Doug Wood (a PhD student) and me in 1989. The sources were selected from earlier radio continuum surveys of the Galactic plane that were also luminous in the IRAS point source catalog at 100 µm and their FIR SEDs were almost identical for all the sources in the observing list. This told us that most of the energy from the central star(s) of the HII regions was absorbed by circumstellar dust and reradiated at FIR wavelengths. The luminosities, compactness, and high emission measures of the observed HII regions implied that we were observing massive protostars in a relatively short period of rapid accretion while still embedded in their natal molecular cloud. Five recurring morphologies were identified in this survey: spherical or unresolved, cometary, core-halo, shell, and irregular. Based on the multiplicity of radio sources found in the field of view of UC HII regions also suggested that UC HII regions are associated with clusters of lower mass stars. The number of UC HII regions observed in this survey suggested that the UC HII phase of evolution of massive star formation must last for a significant fraction of the main sequence lifetime of a massive star and is inconsistent with the short (<3x10$^4$ years) expected for unimpeded expansion out of the UC phase. It was suggested that the UC phase of HII regions could be increased by motion of the protostar through its natal molecular cloud, which could explain cometary and shell-like morphologies, or it could be due to expansion of the HII region into an external density gradient. This was a point of discussion for several years after publication of the Wood and Churchwell (WC 89A) paper. A follow-up paper by Wood and Churchwell in 1989 (WC89B) investigated the FIR color-color limits of UC HII regions and showed that they are tightly bound to the Galactic plane (scale height 0.60°±0.05°, which is essentially the same as that of known O stars. The WC89A survey was followed up by an additional one by Stan Kurtz (PhD student), me, and Doug Wood in 1994 (KEW94), which improved the statistics of the properties and morphologies of UC HII regions. These two papers motivated a period of about 10 years of detailed observations of UC HII regions to obtain accurate morphologies and more detailed investigations of the earliest stages of formation and evolution of massive star formation.

**Q:** In 2006-7 you published two papers about ‘The Bubbling Galactic Disk’ based on the Spitzer GLIMPSE project. What are these bubbles?

**A:** The GLIMPSE false color images showed very early on that the Galactic disk is full of bubbles. I think by now the Zooniverse Project has identified a thousand or more probable bubbles in the Galaxy. The GLIMPSE bands 3.6 and 4.5 µm are generally portrayed in blue and primarily trace stars and scattered stellar light. The 5.8 and 8.0 µm bands are portrayed in green and represent primarily polycyclic aromatic hydrocarbons (PAHs), and the 24 µm band from the MIPSGAL survey primarily represents thermal dust emission. There is an obvious order of the wavelength emission distributions. In general the bubbles have a bright rim of 8 µm emission that tapers off with distance from the center. Interior to the 8 µm shell, thermal dust emission dominates the emission at 24 µm, indicating that warm dust is well mixed with the ionized hydrogen. This is confirmed by comparing the 24 µm emission with 21 cm continuum emission that traces ionized hydrogen. In bubbles ionized by central stars with strong stellar winds, there is clear evidence of a region in the immediate vicinity of the star that has been evacuated by the wind so that both ionized hydrogen and dust have been evacuated. Also, there is clear evidence that PAHs are not present in the ionized hydrogen as traced by radio continuum emission and thermal dust emission. This is strong evidence that PAHs are destroyed by hard UV...
radiation. However, PAHs are bright just outside the hydrogen ionization front, indicating that soft UV photons are required to excite PAHs but they are easily destroyed by more energetic photons. So back to your question, what are the bubbles? It is quite clear that they are HII regions ionized by O and early B stars. We know this because a few of the bubbles have identified ionizing stars. Also, most of them coincide with radio continuum emission. A detailed analysis of the properties of one bubble, N49 in the bubble catalog, has been published by Everett and Churchwell (2010, ApJ, 713, 592). This paper analyzed the role of dust in HII regions, which showed that dust is the primary coolant in the shocked wind and makes the nebula appear to be ionized by a cooler star than is actually the case. They also proposed that dust must be continuously replenished because dust would otherwise be swept out of the nebula on short time scales relative to the age of the HII region by the stellar wind and the intense stellar radiation field. Another aspect of the GLIMPSE images is that PAHs are widely distributed in the diffuse ISM well away from HII regions. The inner Galactic disk is literally permeated with diffuse PAH emission. This seems to imply that the diffuse ISM is permeated by soft UV radiation and that even areas where PAHs are not seen, do not necessarily imply an absence of PAHs, but possibly an absence of soft UV radiation due to a decrease in the number of nearby hot stars and HII regions.

Q: You have been heavily involved with the GLIMPSE surveys. Please give an overview of some other results that in particular interested you.

A: Yes I was the PI of the GLIMPSE legacy program. This project took over my life in 2000. We had 3.5 years lead time before launch to develop an automated pipeline. We knew that when observations started we would not be able to keep up with data reduction and analysis in real time. A huge amount of time was invested to assure that we could achieve a reliability for our point source catalog ≥99.5%. Much time was also taken up on dealing with known and possible detector artifacts, deleting cosmic ray hits, and how to sew the 10s of thousands of individual 5′×5′ frames into a seamless single image with little or no apparent image boundaries. I had an excellent group of co-workers on my team and the project became a great success. Among the main results from my point of view are as follows: The clear display of how widely PAHs are distributed in the general ISM, especially in the inner 30° of the Galactic center. The Galaxy has no deficit of hydrocarbons. The wide distribution of PAHs raise a number of important questions. How are such complex molecules formed? How did they get so widely distributed into the ISM? Will they require an increase of the standard C/H abundance ratio? We also found that there is a serious imbalance in the stellar density between the 1st and 4th quadrants of the Galaxy. The stellar density in the 1st quadrant is ~25% greater than in 4th quadrant within ~50° of the Galactic center. It turns out that this is due to what is now referred to as the ‘long bar’ through the Galactic center. The bar extends out to about 30° in the 1st quadrant and has an angle of 45° to the line from the Sun to the Galactic center. The GLIMPSE images also show an enhancement of HII regions and massive star formation near the end of the bar in the 1st quadrant. In the meantime, the other end of the long bar in the 4th quadrant has been detected using red clump giants as tracers. It only extends out to ~15° from the Galactic center due to geometric projection. This part of the bar was not apparent in star counts due to confusion in this part of the Galaxy. I was also surprised at how the IRAC bands delineate so clearly the different components of bubbles around HII regions. The clean delineation of warm thermal dust emission and PAH shells place important constraints on models of these regions and put them on a much sounder footing. A discovery that has gotten relatively little attention so far, but I think may turn out to be one of the more important discoveries, are the EGOs (Extended Green Objects). Many of these have been analyzed and studied in radio line and continuum emission by Claudia Cyganowski (my last PhD student). EGOs are small ‘bowtie shaped’ objects that show up in the 4.5 μm band of the IRAC camera, which in GLIMPSE images was usually assigned a green color. After radio molecular line and continuum images were obtained, it was shown that EGOs are massive protostars in an early stage of mass accretion accompanied by strong bipolar outflows. The 4.5 μm band has two strong H2 lines that can be excited by shocks. We believe that the 4.5 μm emission is enhanced when the bipolar outflows crash into the ambient interstellar medium and shock excites the H2 line emission. This interpretation has been confirmed by high resolution images of class I and class II methanol masers. The 6.7 GHz class II maser is excited by radiation and is always centered on the exciting star of the outflow where the radiation field is most intense, and the 44 GHz class I maser is excited by collisions and they are located along the outflows traced by 4.5 μm emission in the GLIMPSE images. This was a beautiful piece of research based on GLIMPSE images combined with radio line and continuum emission. Finding a probe to detect rare massive protostars in this short phase of rapid growth via accretion will add a critically needed tool for understanding the earliest phases of massive star formation. Of course, the ~900 published papers that used GLIMPSE images and catalogs say a lot more about the contributions of the GLIMPSE survey.
Perspective
The Role of Turbulence for Star Formation
Christoph Federrath

1 The role of turbulence, magnetic fields and feedback for the star formation rate

Star formation powers the evolution of galaxies and sets the initial conditions for planet formation. However, the relative importance of gravity, turbulence, magnetic fields and feedback during star formation are still not well understood. Recent advances in numerical and theoretical modelling, and more powerful observatories such as ALMA help us to better understand the role of turbulence for star formation. From this it seems likely that the complex interplay between gravity, turbulence, magnetic fields, and feedback is controlling the formation of stars, and only their combination yields reasonable star formation rates (Federrath, 2015) – see Figure 1.

Indeed, magneto-hydrodynamical turbulence and feedback play a crucial role in limiting the rate of star formation. This turbulence-regulated picture of the formation of stars (MacLow & Klessen, 2004; Elmegreen & Scalo, 2004; McKee & Ostriker, 2007; Hennebelle & Falgarone, 2012; Federrath & Klessen, 2012; Padoan et al., 2014) has recently allowed us to make powerful predictions for the star formation rate (SFR) of molecular clouds in the Milky Way disk and near the Galactic Centre (Federrath et al., 2008, 2010b; Price et al. 2011; Molina et al. 2012; Nolan et al. 2015; Federrath & Banerjee, 2015). The consequence is that compressive driving produces up to an order of magnitude higher SFRs than solenoidal driving for otherwise similar cloud parameters (Federrath & Klessen, 2012). This difference may also contribute significantly to the fact that star formation in the central molecular zone (CMZ) of our Galaxy is relatively inefficient, considering the very high gas densities in the CMZ. This is because strong shear flows induce solenoidal turbulence, which reduces the SFR compared to compressive driving (Federrath et al., 2016, 2017b) and successfully predicts SFR \( \sim 10^{-2} \, \text{M}_\odot \, \text{yr}^{-1} \) or an SFR per freefall time of \( \sim 4\% \), subsequently observed for the CMZ cloud G0.253+0.016 “The Brick” (Barnes et al. 2017).

Most feedback mechanisms (e.g., supernova explosions and high-mass stellar winds), but also accretion and Galactic spiral shocks drive primarily compressible (curl-free) modes, so we refer to these drivers as “compressive drivers”. By contrast, solenoidal (divergence-free) modes are generated by shear and magneto-rotational instability (so we call them “solenoidal drivers”). Many turbulence drivers excite a mixture of solenoidal and compressible modes in the velocity and density field of the clouds – for example, jets rotate and induce shear flows between the inner and outer parts of the jet, thus driving solenoidal motions. But at the tip of the jet, the bow shock induces compression. The key point about the turbulence driving is that the gas density probability distribution function (PDF) depends critically on the driving and so does the amount of dense gas from which stars form (Federrath et al., 2008, 2010b; Price et al. 2011; Molina et al. 2012; Nolan et al. 2015; Federrath & Banerjee, 2015). The consequence is that compressive driving produces up to an order of magnitude higher SFRs than solenoidal driving for otherwise similar cloud parameters (Federrath & Klessen, 2012). This difference may also contribute significantly to the fact that star formation in the central molecular zone (CMZ) of our Galaxy is relatively inefficient, considering the very high gas densities in the CMZ. This is because strong shear flows induce solenoidal turbulence, which reduces the SFR compared to compressive driving (Federrath et al., 2016, 2017b) and successfully predicts SFR \( \sim 10^{-2} \, \text{M}_\odot \, \text{yr}^{-1} \) or an SFR per freefall time of \( \sim 4\% \), subsequently observed for the CMZ cloud G0.253+0.016 “The Brick” (Barnes et al. 2017).

Figure 3 shows two simulations of star cluster formation in clouds: one with solenoidal driving (left-hand panel) and another one with compressive driving (right-hand panel). The ratio of kinetic to gravitational energy, i.e., the virial parameter \( \alpha_{\text{vir}} \sim 1 \) and the turbulent Mach number \( \mathcal{M} \sim 10 \) as well as any other cloud parameters were held con-
Figure 1: Star formation rate per freefall time in four numerical simulation models with increasing physical complexity: Gravity only (red dash-dotted), Gravity vs. Turbulence (green dashed), Gravity vs. Turbulence + Magnetic Fields (blue dotted), and Gravity vs. Turbulence + Magnetic Fields + Jet/Outflow Feedback (black solid). Only the combination of gravity, turbulence, magnetic fields, and feedback yields observed star formation rates (Federrath, 2015). Simulation movies available: [http://www.mso.anu.edu.au/~chfeder/pubs/ineff_sf/ineff_sf.html](http://www.mso.anu.edu.au/~chfeder/pubs/ineff_sf/ineff_sf.html).

Figure 2: Turbulence-regulated paradigm of star formation. Turbulence is driven by stellar feedback (e.g., supernovae, winds, jets) and/or large-scale dynamics (e.g., galactic shear, accretion, magneto-rotational instability). Some of these turbulence driving mechanisms excite more solenoidal (rotational) modes, others drive more compressive (potential) modes. The mixture of turbulent modes has profound consequences for star formation (see Fig. 3).

stant between these two simulations, so this probes solely the change in SFR due to the turbulent driving. We see that the SFR is more than an order of magnitude higher in the compressive driving case, compared to the solenoidal driving case. This demonstrates that the turbulence driving is a crucial ingredient for predicting and understanding the rate of star formation in Galactic clouds.

Observations of Milky Way clouds (Padoan et al., 1997; Brunt, 2010; Kainulainen et al., 2013; Schneider et al., 2013; Ginsburg et al. 2013; Burkhart et al., 2017; Orkisz et al., 2017) and recent numerical simulations of molecu-
The SFR is a factor of $\sim 15$–20 different between these two cases, which is well reproduced in the theoretical turbulence-regulated theory. The theory predicts the star formation rate (SFR) based on four cloud parameters only: 1) the virial parameter $\alpha_{\text{vir}}$ (ratio of kinetic to gravitational energy of the cloud), 2) the Mach number $\mathcal{M}$, 3) the driving of the turbulence, and 4) the plasma $\beta$ (ratio of thermal to magnetic pressure of the cloud). In these particular simulations, $\alpha_{\text{vir}} \sim 1$, $\mathcal{M} \sim 10$, and $\beta \to \infty$, but a parameter sweep covering virtually all cloud conditions in the Milky Way shows that the theoretical model provides very good predictions of the SFR for the entire range of cloud parameters (Federrath & Klessen, 2012). Simulation movies available: [http://www.mso.anu.edu.au/~chfeder/pubs/sfr/sfr.html](http://www.mso.anu.edu.au/~chfeder/pubs/sfr/sfr.html).

Figure 4: Theoretical model of the stellar initial mass function (IMF) by Hennebelle & Chabrier (2008, 2009). The IMF is expected to vary with the driving of the turbulence (e.g., solenoidal versus compressive) and with the Mach number. A challenge for future simulations and observations is to test the theoretical predictions of the IMF.

The IMF is the mass distribution of stars when they are born. The origin of the IMF is one of the most puzzling riddles in astrophysics (Offner et al., 2014). We know from observational surveys that most stars have masses less than about half the mass of our Sun. Stars with smaller and higher masses are rarer. The high-mass tail of the IMF is a decreasing power-law function with the number of stars, $N(M) \propto M^{-1.35}$ (Salpeter, 1955; Kroupa, 2001; Muench et al., 2002; Chabrier, 2003). Understanding this seemingly universal power-law tail and the turnover at $\sim 0.1 M_\odot$ is one of the most challenging open problems of astrophysics.

Figure 3: Star cluster formation simulations with solenoidal turbulence driving (left) and compressive driving (right). The SFR is a factor of $\sim 15$–20 different between these two cases, which is well reproduced in the theoretical turbulence-regulated theory. The theory predicts the star formation rate (SFR) based on four cloud parameters only: 1) the virial parameter $\alpha_{\text{vir}}$ (ratio of kinetic to gravitational energy of the cloud), 2) the Mach number $\mathcal{M}$, 3) the driving of the turbulence, and 4) the plasma $\beta$ (ratio of thermal to magnetic pressure of the cloud). In these particular simulations, $\alpha_{\text{vir}} \sim 1$, $\mathcal{M} \sim 10$, and $\beta \to \infty$, but a parameter sweep covering virtually all cloud conditions in the Milky Way shows that the theoretical model provides very good predictions of the SFR for the entire range of cloud parameters (Federrath & Klessen, 2012). Simulation movies available: [http://www.mso.anu.edu.au/~chfeder/pubs/sfr/sfr.html](http://www.mso.anu.edu.au/~chfeder/pubs/sfr/sfr.html).

2 The next big challenge: the initial mass function (IMF) of stars

The IMF has far-reaching consequences and applications. It is needed to interpret the colours, brightness and star formation activity of all galaxies in our Universe. It is the central ingredient for understanding galaxy formation and evolution, because the feedback from stars is what powers the life cycle and the elemental abundances of galaxies. Equally important is the role of star formation for the origin of planets and life, because planets form in the swirling, dusty gas disks around young stars, where the radiation, gravity and mass of the star, and thus the IMF, control the formation of planets. This motivates the next
big challenge: the theoretical understanding of the origin of stellar masses, i.e., the IMF. In order to understand the IMF, we must determine its dependence on characteristics of the parental molecular cloud – including the driving source and intensity of the cloud turbulence, the magnetic field strength, and the feedback from young stars, i.e., jets, outflows and radiation feedback. Unravelling the origin of the IMF will require some of the most sophisticated numerical techniques and will require including a wide range of physical processes, gravity, turbulence, magnetic fields, and feedback, all at the very highest numerical resolution currently available with supercomputer technology. Finally, in order to enable meaningful comparisons against observations we will need radiative transfer calculations and forward modelling to match physical quantities (e.g., volumetric density) to observationally accessible quantities (e.g., column density).

A promising theoretical framework of the IMF was put forward by Hennebelle & Chabrier, 2008, 2009, based on the statistics of supersonic turbulence and the density PDF. Figure 4 shows a key prediction from this theory, namely that the peak of the IMF would be sensitive to the driving of the turbulence. We see that the peak of the IMF shifts to smaller characteristic masses when the turbulence becomes more compressive. However, this theoretical prediction needs to be tested.

Recent numerical studies have started to attack this IMF problem (Girichidis et al., 2011, Krumholz et al. 2012; Bertelli Motta et al., 2016; Liptai et al., 2017). But numerical studies of the IMF remain largely inconclusive, because of either low number statistics (i.e., insufficient sampling of the IMF produced in the simulations), the absence of radiative feedback, absence of magnetic fields, or that only an initial turbulent velocity field was imposed instead of continuous driving. Moreover, practically all of these simulations have star formation rates at least an or-
order of magnitude higher than typically observed, due to either the isolated boundary conditions or the absence of magnetic fields and/or feedback processes, all resulting in too strong gravitational collapse. Another critical issue is convergence with numerical resolution, which is extremely hard to achieve in studies of gas fragmentation into the IMF (Federrath et al., 2017a).

With the development of subgrid models for jet and outflow feedback (Li & Nakamura, 2006; Wang et al., 2010; Cunningham et al., 2011; Federrath et al., 2014), radiation feedback, and our existing modelling capabilities for gravity, turbulence and magnetic fields, we will soon be able to simultaneously include the most important physical processes that determine the fragmentation of the gas to the IMF.

However, even though these subgrid models will soon allow us to run large parameter studies to test the predictions of the IMF theories, especially their proposed dependence on the IMF, it is clear that we still need to run large parameter studies to test the predictions of the IMF.

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Macleod, J., Mac Low, M.-M., & Klessen, R. S. 2004, RevMP, 76, 125
A Statistical Spectropolarimetric Study of Herbig Ae/Be Stars
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We present Hα linear spectropolarimetry of a large sample of Herbig Ae/Be stars. Together with newly obtained data for 17 objects, the sample contains 56 objects, the largest such sample to date. A change in linear polarization across the Hα line is detected in 42 (75%) objects, which confirms the previous finding that the circumstellar environment around these stars on small spatial scales has an asymmetric structure, which is typically identified with a disk. A second outcome of this research is that we confirm that Herbig Ae stars are similar to T Tauri stars in displaying a line polarization effect, while depolarization is more common among Herbig Be stars. This finding had been suggested previously to indicate that Herbig Ae stars form in the same manner than T Tauri stars through magnetospheric accretion. It appears that the transition between these two differing polarization line effects occurs around the B7–B8 spectral type. This would in turn not only suggest that Herbig Ae stars accrete in a similar fashion as lower mass stars, but also that this accretion mechanism switches to a different type of accretion for Herbig Be stars. We report that the magnitude of the line effect caused by electron scattering close to the stars does not exceed 2%. Only a very weak correlation is found between the magnitude of the line effect and the spectral type or the strength of the Hα line. This indicates that the detection of a line effect only relies on the geometry of the line-forming region and the geometry of the scattering electrons.

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Improved torque formula for low and intermediate mass planetary migration
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The migration of planets on nearly circular, non-inclined orbits in protoplanetary discs is entirely described by the disc’s torque. This torque is a complex function of the disc parameters, and essentially amounts to the sum of two components: the Lindblad torque and the corotation torque. Known torque formulae do not reproduce accurately the torque actually experienced in numerical simulations by low- and intermediate- mass planets in radiative discs. One of the main reasons for this inaccuracy is that these formulae have been worked out in two-dimensional analyses. Here we revisit the torque formula and update many of its dimensionless coefficients by means of tailored, three-dimensional numerical simulations. In particular, we derive the dependence of the Lindblad torque on the temperature gradient, the dependence of the corotation torque on the radial entropy gradient (and work out a suitable expression of this gradient in a three-dimensional disc). We also work out the dependence of the corotation torque on the radial temperature gradient, overlooked so far. Corotation torques are known to scale very steeply with the width of the horseshoe region. We extend the expression of this width to the domain of intermediate mass planets, so that our updated torque formula remains valid for planets up to typically several tens of Earth masses, provided these relatively massive planets do not significantly deplete their coorbital region. Our torque expression can be applied to low- and intermediate-mass planets in optically thick protoplanetary discs, as well as protomoons embedded in circumplanetary discs.

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The shapes of column density PDFs - The importance of the last closed contour

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The probability distribution function of column density (PDF) has become the tool of choice for cloud structure analysis and star formation studies. Its simplicity is attractive, and the PDF could offer access to cloud physical parameters otherwise difficult to measure, but there has been some confusion in the literature on the definition of its completeness limit and shape at the low column density end. In this Letter we use the natural definition of the completeness limit of a column density PDF, the last closed column-density contour inside a surveyed region, and apply it to a set of large-scale maps of nearby molecular clouds. We conclude that there is no observational evidence for log-normal PDFs in these objects. We find that all studied molecular clouds have PDFs well described by power-laws, including the diffuse cloud Polaris. Our results call for a new physical interpretation for the shape of the column density PDFs. We find that the slope of a cloud PDF is invariant to distance but not to the spatial arrangement of cloud material, and as such it is still a useful tool to investigate cloud structure.

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Destruction of Refractory Carbon in Protoplanetary Disks

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The Earth and other rocky bodies in the inner solar system contain significantly less carbon than the primordial materials that seeded their formation. These carbon-poor objects include the parent bodies of primitive meteorites, suggesting that at least one process responsible for solid-phase carbon depletion was active prior to the early stages of planet formation. Potential mechanisms include the erosion of carbonaceous materials by photons or atomic oxygen in the surface layers of the protoplanetary disk. Under photochemically generated favorable conditions, these reactions can deplete the near-surface abundance of carbon grains and polycyclic aromatic hydrocarbons by several orders of magnitude on short timescales relative to the lifetime of the disk out to radii of ~20–100+ au from the central star depending on the form of refractory carbon present. Due to the reliance of destruction mechanisms on a high influx of photons, the extent of refractory carbon depletion is quite sensitive to the disk’s internal radiation field. Dust transport within the disk is required to affect the composition of the midplane. In our current model of a passive, constant-α disk, where α = 0.01, carbon grains can be turbulently lofted into the destructive surface layers and depleted out to radii of ~3–10 au for 0.1–1 µm grains. Smaller grains can be cleared out of the planet-forming region completely. Destruction may be more effective in an actively accreting disk or when considering individual grain trajectories in non-idealized disks.

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How do binary clusters form?

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Approximately 10 per cent of star clusters are found in pairs, known as binary clusters. We propose a mechanism for binary cluster formation; we use N-body simulations to show that velocity substructure in a single (even fairly smooth) region can cause binary clusters to form. This process is highly stochastic and it is not obvious from a region’s initial conditions whether a binary will form and, if it does, which stars will end up in which cluster. We find the probability that a region will divide is mainly determined by its virial ratio, and a virial ratio above ‘equilibrium’ is generally necessary for binary formation. We also find that the mass ratio of the two clusters is strongly influenced by the initial degree of spatial substructure in the region.

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ALMA Observations of the Protostar L1527 IRS: Probing Details of the Disk and the Envelope Structures

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We have newly observed the Class 0/I protostar L1527 IRS using the Atacama Large Millimeter/submillimeter Array (ALMA) during its Cycle 1 in 220 GHz dust continuum and C¹⁸O (J=2-1) line emissions with a ~2 times higher angular resolution (~0.5″) and ~4 times better sensitivity than our ALMA Cycle 0 observations. Continuum emission shows elongation perpendicular to the associated outflow, with a deconvolved size of 0.53″ x 0.15″. C¹⁸O emission shows similar elongation, indicating that both emissions trace the disk and the flattened envelope surrounding the protostar. The velocity gradient of the C¹⁸O emission along the elongation due to rotation of the disk/envelope system is re-analyzed, identifying Keplerian rotation proportional to r⁻⁰.₅ more clearly than the Cycle 0 observations. The Keplerian-disk radius and the dynamical stellar mass are kinematically estimated to be ~74 AU and ~0.45 M☉, respectively. The continuum visibility is fitted by models without any annulus averaging, revealing that the disk is in hydrostatic equilibrium. The best-fit model also suggests a density jump by a factor of ~5 between the disk and the envelope, suggesting that disks around protostars can be geometrically distinguishable from the envelope from a viewpoint of density contrast. Importantly, the disk radius geometrically identified with the density jump is consistent with the radius kinematically estimated. Possible origin of the density jump due to the mass accretion from the envelope to the disk is discussed. C¹⁸O observations can be reproduced by the same geometrical structures derived from the dust observations, with possible C¹⁸O freeze-out and localized C¹⁸O desorption.

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Lithium depletion in solar-like stars: effect of overshooting based on realistic multi-dimensional simulations

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We study lithium depletion in low-mass and solar-like stars as a function of time, using a new diffusion coefficient describing extra-mixing taking place at the bottom of a convective envelope. This new form is motivated by multi-dimensional fully compressible, time implicit hydrodynamic simulations performed with the MUSIC code. Intermittent convective mixing at the convective boundary in a star can be modeled using extreme value theory, a statistical analysis frequently used for finance, meteorology, and environmental science. In this letter, we implement this statistical diffusion coefficient in a one-dimensional stellar evolution code, using parameters calibrated from multi-dimensional hydrodynamic simulations of a young low-mass star. We propose a new scenario that can explain observations of the surface abundance of lithium in the Sun and in clusters covering a wide range of ages, from \( \sim 50 \text{ Myr} \) to \( \sim 4 \text{ Gyr} \). Because it relies on our physical model of convective penetration, this scenario has a limited number of assumptions. It can explain the observed trend between rotation and depletion, based on a single additional assumption, namely that rotation affects the mixing efficiency at the convective boundary. We suggest the existence of a threshold in stellar rotation rate above which rotation strongly prevents the vertical penetration of plumes and below which rotation has small effects. In addition to providing a possible explanation for the long standing problem of lithium depletion in pre-main sequence and main sequence stars, the strength of our scenario is that its basic assumptions can be tested by future hydrodynamic simulations.

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The Young L Dwarf 2MASS J11193254−1137466 is a Planetary-mass Binary

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We have discovered that the extremely red, low-gravity L7 dwarf 2MASS J11193254−1137466 is a 0.14″ (3.6 au) binary using Keck laser guide star adaptive optics imaging. 2MASS J11193254−1137466 has previously been identified as a likely member of the TW Hydrae Association (TWA). Using our updated photometric distance and proper motion, a kinematic analysis based on the BANYAN II model gives an 82% probability of TWA membership. At TWA’s 10\( \pm \)3 Myr age and using hot-start evolutionary models, 2MASS J11193254−1137466AB is a pair of 3.7\( ^{+1.2}_{-0.9} \) \( M_{\text{Jup}} \) brown dwarfs, making it the lowest-mass binary discovered to date. We estimate an orbital period of 90\( ^{+80}_{-50} \) years. One component is marginally brighter in \( K \) band but fainter in \( J \) band, making this a probable flux-reversal binary, the first discovered with such a young age. We also imaged the spectrally similar TWA L7 dwarf WISEA J114724.10−204021.3 with Keck and found no sign of binarity. Our evolutionary model-derived \( T_{\text{eff}} \) estimate for WISEA J114724.10−204021.3 is \( \approx 230 \text{ K} \) higher than for 2MASS J11193254−1137466AB, at odds with the spectral similarity of the two objects. This discrepancy suggests that WISEA J114724.10−204021.3 may actually be a tight binary with masses and temperatures very similar to 2MASS J11193254−1137466AB, or further supporting the idea that near-infrared spectra of young ultracool dwarfs are shaped by factors other than temperature and gravity. 2MASS J11193254−1137466AB will be an essential benchmark for testing evolutionary and atmospheric models in the young planetary-mass regime.


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Dynamical Ejections of Stars due to an Accelerating Gas Filament

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Observations of the Orion-A integral shaped filament (ISF) have shown indications of an oscillatory motion of the gas filament. This evidence is based on both the wave-like morphology of the filament as well as the kinematics of the gas and stars, where the characteristic velocities of the stars require a dynamical heating mechanism. As proposed by Stutz and Gould (2016), such a heating mechanism (the “Slingshot”) may be the result of an oscillating gas filament in a gas-dominated (as opposed to stellar-mass dominated) system. Here we test this hypothesis with the first stellar-dynamical simulations in which the stars are subjected to the influence of an oscillating cylindrical potential. The accelerating, cylindrical background potential is populated with a narrow distribution of stars. By coupling the potential to N-body dynamics, we are able to measure the influence of the potential on the stellar distribution. The simulations provide evidence that the slingshot mechanism can successfully reproduce several stringent observational constraints. These include the stellar spread (both in projected position and in velocity) around the filament, the symmetry in these distributions, and a bulk motion of the stars with respect to the filament. Using simple considerations we show that star-star interactions are incapable of reproducing these spreads on their own when properly accounting for the gas potential. Thus, properly accounting for the gas potential is essential for understanding the dynamical evolution of star forming filamentary systems in the era of Gaia.

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Wide σ Orionis binaries resolved by UKIDSS

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In spite of its importance for the study of star formation at all mass domains, the nearby young σ Orionis cluster still lacks a comprehensive survey for multiplicity. We try to fill that observational gap by looking for wide resolved binaries with angular separations between 0\textdegree.4 and 4\textdegree.0. We search for companions to 331 catalogued cluster stellar members and candidates in public $K$-band UKIDSS images outside the innermost 1\textarcmin, which is affected by the glare of the bright, eponymous σ Ori multiple system, and investigate their cluster membership with colour-magnitude diagrams and previous knowledge of youth features. Of the 18 identified pairs, ten have very low individual probabilities of chance alignment (<1%) and are considered here as physical pairs. Four of them are new, while the other six had been discovered previously, but never investigated homogeneously and in detail. Projected physical separations and magnitude differences of the ten probably bound pairs range from 180 to 1220 au, and from 0.0 to 3.4 mag in $K$, respectively. Besides, we identify two cluster stars with elongated point spread functions. We determine the minimum frequency of wide multiplicity in the interval of projected physical separations $s = 160$–1600 au in σ Orionis at 3.0$^{+1.2}_{-1.1}$%. We discover a new Lindroos system, find that massive and X-ray stars tend to be in pairs or trios, conclude that multiplicity truncates circumstellar discs and enhances X-ray emission, and ascribe a reported lithium depletion in a young star to unresolved binarity in spectra of moderate resolution. When accounting for all know multiples, including spectroscopic binaries, the minimum frequency of multiplicity increases to about 10%, which implies that of the order of 80–100 unknown multiple systems still await discovery in σ Orionis.

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Search for grain growth towards the center of L1544

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In dense and cold molecular clouds dust grains are surrounded by thick icy mantles. It is however not clear if dust growth and coagulation take place before the switch-on of a protostar. This is an important issue, as the presence of large grains may affect the chemical structure of dense cloud cores, including the dynamically important ionization fraction, and the future evolution of solids in protoplanetary disks. To study this further, we focus on L1544, one of the most centrally concentrated pre-stellar cores on the verge of star formation, and with a well-known physical structure. We observed L1544 at 1.2 and 2 mm using NIKA, a new receiver at the IRAM 30 m telescope, and we used data from the Herschel Space Observatory archive. We find no evidence of grain growth towards the center of L1544 at the available angular resolution. Therefore, we conclude that single dish observations do not allow us to investigate grain growth toward the pre-stellar core L1544 and high sensitivity interferometer observations are needed. We predict that dust grains can grow to 200 $\mu$m in size toward the central $\sim$300 au of L1544. This will imply a dust opacity change by a factor of $\sim$2.5 at 1.2 mm, which can be detected using the Atacama Large Millimeter and submillimeter Array (ALMA) at different wavelengths and with an angular resolution of $2''$.

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Hydrodynamics of embedded planets’ first atmospheres - III. The role of radiation transport for super-Earth planets

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The population of close-in super-Earths, with gas mass fractions of up to 10% represents a challenge for planet formation theory: how did they avoid runaway gas accretion and collapsing to hot Jupiters despite their core masses being in the critical range of $M_c \approx 10 M_\oplus$? Previous three-dimensional (3D) hydrodynamical simulations indicate that atmospheres of low-mass planets cannot be considered isolated from the protoplanetary disc, contrary to what is assumed in 1D-evolutionary calculations. This finding is referred to as the recycling hypothesis. In this Paper we investigate the recycling hypothesis for super-Earth planets, accounting for realistic 3D radiation hydrodynamics. Also, we conduct a direct comparison in terms of the evolution of the entropy between 1D and 3D geometries. We clearly see that 3D atmospheres maintain higher entropy: although gas in the atmosphere loses entropy through radiative cooling, the advection of high entropy gas from the disc into the Bondi/Hill sphere slows down Kelvin-Helmholtz contraction, potentially arresting envelope growth at a sub-critical gas mass fraction. Recycling, therefore, operates vigorously, in line with results by previous studies. However, we also identify an “inner core” – in size $\approx 25\%$ of the Bondi radius – where streamlines are more circular and entropies are much lower than in the outer atmosphere. Future studies at higher resolutions are needed to assess whether this region can become hydrodynamically-isolated on long time-scales.

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Molecular clumps photoevaporation in ionized regions

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We study the photoevaporation of molecular clumps exposed to a UV radiation field including hydrogen-ionizing photons ($h\nu > \mu\text{eV}$) produced by massive stars or quasars. We follow the propagation and collision of shock waves inside clumps and take into account self-shielding effects, determining the evolution of clump size and density with time. The structure of the ionization-photodissociation region (iPD) is obtained for different initial clump masses ($M = 0.01–10^4 M_\odot$) and impinging fluxes ($G_0 = 10^2–10^5$ in units of the Habing flux). The cases of molecular clumps engulfed in the HII region of an OB star and clumps carried within quasar outflows are treated separately. We find that the clump undergoes in both cases an initial shock-contraction phase and a following expansion phase, which lets the radiation penetrate in until the clump is completely evaporated. Typical evaporation time-scales are $\approx 0.01$ Myr in the stellar case and 0.1 Myr in the quasar case, where the clump mass is 0.1 $M_\odot$ and $10^3 M_\odot$ respectively. We find that clump lifetimes in quasar outflows are compatible with their observed extension, suggesting that photoevaporation is the main mechanism regulating the size of molecular outflows.

How fast is mass-segregation happening in hierarchical formed embedded star clusters?

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We investigate the evolution of mass segregation in initially sub-structured young embedded star clusters with two different background potentials mimicking the gas. Our clusters are initially in virial or sub-virial global states and have different initial distributions for the most massive stars: randomly placed, initially mass segregated or even inverse segregation. By means of N-body simulation we follow their evolution for 5 Myr. We measure the mass segregation using the minimum spanning tree method $\Lambda_{MSR}$ and an equivalent restricted method. Despite this variety of different initial conditions, we find that our stellar distributions almost always settle very fast into a mass segregated and more spherical configuration, suggesting that once we see a spherical or nearly spherical embedded star cluster, we can be sure it is mass segregated no matter what the real initial conditions were. We, furthermore, report under which circumstances this process can be more rapid or delayed, respectively.

The evolution of Giant Molecular Filaments

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In recent years there has been a growing interest in studying giant molecular filaments (GMFs), which are extremely elongated (more than 100pc in length) giant molecular clouds (GMCs). They are often seen as inter-arm features in external spiral galaxies, but have been tentatively associated with spiral arms when viewed in the Milky Way. In this paper, we study the time evolution of GMFs in a high-resolution section of a spiral galaxy simulation, and their
link with spiral arm GMCs and star formation, over a period of 11Myrs. The GMFs generally survive the inter-arm passage, although they are subject to a number of processes (e.g. star formation, stellar feedback and differential rotation) which can break the giant filamentary structure into smaller sections. The GMFs are not gravitationally bound clouds as a whole, but are, to some extent, confined by external pressure. Once they reach the spiral arms, the GMFs tend to evolve into more substructured spiral arm GMCs, suggesting that GMFs may be precursors to arm GMCs. Here, they become incorporated into the more complex and almost continuum molecular medium that makes up the gaseous spiral arm. Instead of retaining a clear filamentary shape, their shapes are distorted both by their climbing up the spiral potential and their interaction with the gas within the spiral arm. The GMFs do tend to become aligned with the spiral arms just before they enter them (when they reach the minimum of the spiral potential), which could account for the observations of GMFs in the Milky Way.

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The OH Masers Towards IRAS 19092+0841
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Context. Maser emission is a strong tool for studying high mass star forming regions and their evolutionary stages. OH masers in particular can trace the circumstellar material around protostars and determine their magnetic field strengths at milliarcsecond resolution.

Aims. Imaging OH maser mission towards high mass protostellar objects to determine their evolutionary stages and to locate the detected maser emission in the process of high mass star formation.

Methods. In 2007, we surveyed OH maser towards 217 high mass protostellar objects to study its presence. In this paper, we present a follow up MERLIN observations of a ground state OH maser emission towards one of these objects, IRAS 19092+0841.

Results. Emission from the two OH main spectral lines, 1665 and 1667 MHz, were detected close to the central object. The positions and velocities of the OH maser features have been determined. The masers are distributed over a region of 500 corresponding to 22400 AU (or 0.1 pc) at a distance of 4.48 kpc. The polarization properties of the OH maser features were determined as well. We identify three Zeeman pairs from which we inferred a magnetic field strength of 4.4mG pointing towards the observer.

Conclusions. The relatively small velocity spread and the relatively wide spacial distribution of the OH maser features support the suggestion that this object could be in an early evolutionary state before the presence of disk and/or jet/outflows.

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Strongly misaligned triple system in SR 24 revealed by ALMA
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We report the detection of the 1.3 mm continuum and the molecular emission of the disks of the young triple system SR24 by analyzing ALMA (The Atacama Large Millimeter/Submillimeter Array) subarcsecond archival observations.
We estimate the mass of the disks (0.025 $M_\odot$ and $4 \times 10^{-5} M_\odot$ for SR24S and SR24N, respectively) and the dynamical mass of the protostars (1.5 and 1.1 $M_\odot$). A kinematic model of the SR24S disk to fit its $^{13}$CO (2–1) emission allows us to develop an observational method to learn what is the tilt of a rotating and accreting disk. We derive the size, the inclination, the position angle and the sense of rotation of each disk, finding that they are strongly misaligned ($108^\circ$) and possibly rotate in opposite directions as seen from Earth, in projection. We compare the ALMA observations with $^{12}$CO SMA archival observations, which are more sensitive to extended structures. We find three extended structures and estimate their masses: a molecular bridge joining the disks of the system, a molecular gas reservoir associated with SR24N and a gas streamer associated with SR24S. Finally we discuss on the possible origin of the misaligned SR24 system, pointing out that a closer inspection of the northern gas reservoir is needed to better understand it.

The circumstellar disk of the B0 protostar powering the HH 80–81 radio jet


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We present subarcsecond angular resolution observations carried out with the Submillimeter Array (SMA) at 880 $\mu$m centered at the B0-type protostar GGD27 MM1, the driving source of the parsec scale HH 80-81 jet. We constrain its polarized continuum emission to be $\lesssim 0.8\%$ at this wavelength. Its submm spectrum is dominated by sulfur-bearing species tracing a rotating disk–like structure (SO and SO$_2$ isotopologues mainly), but also shows HCN-bearing and CH$_3$OH lines, which trace the disk and the outflow cavity walls excavated by the HH 80-81 jet. The presence of many sulfurated lines could indicate the presence of shocked gas at the disk’s centrifugal barrier or that MM1 is a hot core at an evolved stage. The resolved SO$_2$ emission traces very well the disk kinematics and we fit the SMA observations using a thin-disk Keplerian model, which gives the inclination ($47^\circ$), the inner ($\lesssim 170$ AU) and outer ($\sim 950–1300$ AU) radii and the disk’s rotation velocity (3.4 km s$^{-1}$ at a putative radius of 1700 AU). We roughly estimate a protostellar dynamical mass of 4–18 $M_\odot$. MM2 and WMC cores show, comparatively, an almost empty spectra suggesting that they are associated with extended emission detected in previous low-angular resolution observations, and therefore indicating youth (MM2) or the presence of a less massive object (WMC).

Formation of wide-orbit gas giant near the stability limit in multi-stellar systems

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We have investigated the formation of a circumstellar wide-orbit gas giant planet in a multiple stellar system. We consider a model of orbital circularization of a core of the giant planet after it is scattered from an inner disk region by a more massive planet, which was proposed by Kikuchi et al. (2014). We extend their model for single star systems to binary (multiple) star systems, by taking into account tidal truncation of the protoplanetary gas disk by a binary
companion. As an example, we consider wide-orbit gas giant in a hierarchical triple system, HD131399Ab. The best-fit orbit of the planet is that with semimajor axis $\sim 80$ au and eccentricity $\sim 0.35$. Since the binary separation is $\sim 350$ au, it is very close to the stability limit, which is puzzling. With the original core location $\sim 20–30$ au, the core (planet) mass $\sim 50 M_E$ and the disk truncation radius $\sim 150$ au, our model reproduces the best-fit orbit of HD131399Ab. We find that the orbit after the circularization is usually close to the stability limit against the perturbations from the binary companion, since the scattered core accretes gas from the truncated disk. Our conclusion can also be applied for wider or more compact binary systems if the separation is not too large and another planet with $\gtrsim 20-30$ earth masses that scattered the core existed in inner region of the system.

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VLBA imaging of the 3mm SiO maser emission in the disk-wind from the massive protostellar system Orion Source I

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We present the first images of the 28SiO $v=1, J=2-1$ maser emission around the closest known massive young stellar object Orion Source I observed at 86 GHz (3mm) with the VLBA. These images have high spatial ($\sim 0.3$ mas) and spectral ($\sim 0.054$ km/s) resolutions. We find that the 3mm masers lie in an X-shaped locus consisting of four arms, with blue-shifted emission in the south and east arms and red-shifted emission in the north and west arms. Comparisons with previous images of the 28SiO $v=1,2, J=1-0$ transitions at 7mm (observed in 2001-2002) show that the bulk of the $J=2-1$ transition emission follows the streamlines of the $J=1-0$ emission and exhibits an overall velocity gradient consistent with the gradient at 7mm. While there is spatial overlap between the 3mm and 7mm transitions, the 3mm emission, on average, lies at larger projected distances from Source I ($\sim 44$ AU compared with $\sim 35$ AU for 7mm). The spatial overlap between the $v=1, J=1-0$ and $J=2-1$ transitions is suggestive of a range of temperatures and densities where physical conditions are favorable for both transitions of a same vibrational state. However, the observed spatial offset between the bulk of emission at 3mm and 7mm possibly indicates different ranges of temperatures and densities for optimal excitation of the masers. We discuss different maser pumping models that may explain the observed offset.

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MALT-45: A 7mm survey of the southern Galaxy - II. ATCA follow-up observations of 44GHz class I methanol masers

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We detail interferometric observations of 44 GHz class I methanol masers detected by MALT-45 (a 7 mm unbiased auto-correlated spectral-line Galactic-plane survey) using the Australia Telescope Compact Array. We detect 238 maser spots across 77 maser sites. Using high-resolution positions, we compare the class I CH$_3$OH masers to other star formation maser species, including CS (1–0), SiO $v = 0$ and the H$53\alpha$ radio-recombination line. Comparison between the cross- and auto-correlated data has allowed us to also identify quasi-thermal emission in the 44 GHz class I methanol maser line. We find that the majority of class I methanol masers have small spatial and velocity ranges ($<0.5$ pc and $<5$ km s$^{-1}$), and closely trace the systemic velocities of associated clouds. Using 870 µm dust continuum emission from the ATLASGAL survey, we determine clump masses associated with class I masers, and find they are generally associated with clumps between 1000 and 3000 $M_\odot$. For each class I methanol maser site, we use the presence of OH masers and radio recombination lines to identify relatively evolved regions of high-mass star formation; we find that maser sites without these associations have lower luminosities and preferentially appear toward dark infrared regions.

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Consistent dust and gas models for protoplanetary disks: II. Chemical networks and rates

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Aims. We define a small and large chemical network which can be used for the quantitative simultaneous analysis of molecular emission from the near-IR to the submm. We revise reactions of excited molecular hydrogen, which are not included in UMIST, to provide a homogeneous database for future applications.

Methods. We use the thermo-chemical disk modeling code ProDiMo and a standard T Tauri disk model to evaluate the impact of various chemical networks, reaction rate databases and sets of adsorption energies on a large sample of chemical species and emerging line fluxes from the near-IR to the submm wavelength range.

Results. We find large differences in the masses and radial distribution of ice reservoirs when considering freeze-out on bare or polar ice coated grains. Most strongly the ammonia ice mass and the location of the snow line (water) change. As a consequence molecules associated to the ice lines such as N$_2$H$^+$ change their emitting region; none of the line fluxes in the sample considered here changes by more than 25% except CO isotopologues, CN and N$_2$H$^+$ lines. The three-body reaction N+H$_2$+M plays a key role in the formation of water in the outer disk. Besides that, differences between the UMIST 2006 and 2012 database change line fluxes in the sample considered here by less than a factor 2 (a subset of low excitation CO and fine structure lines stays even within 25%); exceptions are OH, CN, HCN, HCO$^+$ and N$_2$H$^+$ lines. However, different networks such as OSU and KIDA 2011 lead to pronounced differences in the chemistry inside 100 au and thus affect emission lines from high excitation CO, OH and CN lines. H$_2$ is easily excited at the disk surface and state-to-state reactions enhance the abundance of CH$^+$ and to a lesser extent HCO$^+$. For sub-mm lines of HCN, N$_2$H$^+$ and HCO$^+$, a more complex larger network is recommended.

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CALYPSO view of SVS 13A with PdBI: Multiple jet sources
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We aim to clarify the origin of the multiple jet features emanating from the binary protostar SVS 13A (= VLA4A/VLA4B). We used the Plateau de Bure Interferometer to map at 0.3–0.8 arcsec (∼70–190 au) dust emission at 1.4 mm, CO(2–1), SiO(5–4), SO(6–5–4–5). Revised proper motions for VLA4A/4B and jet wiggling models are computed to clarify their respective contribution.

VLA4A shows compact dust emission suggestive of a disk <50 au, and is the hot corino source, while CO/SiO/SO counterparts to the small-scale H2 jet originate from VLA4B and reveal the jet variable velocity structure. This jet exhibits ∼3 arcsec, wiggling consistent with orbital motion around a yet undetected ∼20–30 au companion to VLA4B, or jet precession. Jet wiggling combined with velocity variability can explain the large apparent angular momentum in CO bullets. We also uncover a synchronicity between CO jet bullets and knots in the HH7–11 chain demonstrating that they trace two distinct jets. Their ∼300 yr twin outburst period may be triggered by close perihelion approach of VLA4A in an eccentric orbit around VLA4B. A third jet is tentatively seen at PA ∼0°.

SVS13 A harbors at least 2 and possibly 3 distinct jet sources. The CO and HH7-11 jets are launched from quasi-coplanar disks, separated by 20–70 au. Their synchronous major events every 300 yr favor external triggering by close binary interactions, a scenario also invoked for FU Or outbursts.

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A new method to unveil embedded stellar clusters

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In this paper we present a novel method to identify and characterize stellar clusters deeply embedded in a dark molecular cloud. The method is based on measuring stellar surface density in wide-field infrared images using star counting techniques. It takes advantage of the differing H-band luminosity functions (HLFs) of field stars and young stellar populations and is able to statistically associate each star in an image as a member of either the background stellar population or a young stellar population projected on or near the cloud. Moreover, the technique corrects for the effects of differential extinction toward each individual star. We have tested this method against simulations as well as observations. In particular, we have applied the method to 2MASS point sources observed in the Orion A and B complexes, and the results obtained compare very well with those obtained from deep Spitzer and Chandra observations where presence of infrared excess or X-ray emission directly determines membership status for every star. Additionally, our method also identifies unobscured clusters and a low resolution version of the Orion stellar surface density map shows clearly the relatively unobscured and diffuse OB 1a and 1b sub-groups and provides useful insights on their spatial distribution.

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Complex organics in IRAS 4A revisited with ALMA and PdBI: Striking contrast between two neighbouring protostellar cores

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Context: Hot corinos are extremely rich in complex organic molecules (COMs). Accurate abundance measurements of COMs in such objects are crucial to constrain astrochemical models. In the particular case of close binary systems this can only be achieved through high angular resolution imaging.

Aim: We aim to perform an interferometric study of multiple COMs in NGC1333 IRAS 4A, which is a protostellar binary hosting hot corino activity, at an angular resolution that is sufficient to distinguish easily the emission from the two cores separated by 1.8″.

Methods: We used the Atacama Large (sub-)Millimeter Array (ALMA) in its 1.2 mm band and the IRAM Plateau de Bure Interferometer (PdBI) at 2.7 mm to image, with an angular resolution of 0.5″ (120 au) and 1″ (235 au), respectively, the emission from 11 different organic molecules in IRAS 4A. This allowed us to clearly disentangle A1 and A2, the two protostellar cores. For the first time, we were able to derive the column densities and fractional abundances simultaneously for the two objects, allowing us to analyse the chemical differences between them.

Results: Molecular emission from organic molecules is concentrated exclusively in A2, while A1 appears completely devoid of COMs or even simpler organic molecules, such as HNCO, even though A1 is the strongest continuum emitter. The protostellar core A2 displays typical hot corino abundances and its deconvolved size is 70 au. In contrast, the upper limits we placed on COM abundances for A1 are extremely low, lying about one order of magnitude below prestellar values. The difference in the amount of COMs present in A1 and A2 ranges between one and two orders of magnitude. Our results suggest that the optical depth of dust emission at these wavelengths is unlikely to be sufficiently high to completely hide a hot corino in A1 similar in size to that in A2. Thus, the significant contrast in molecular richness found between the two sources is most probably real. We estimate that the size of a hypothetical hot corino in A1 should be less than 12 au.

Conclusions: Our results favour a scenario in which the protostar in A2 is either more massive and/or subject to a higher accretion rate than A1, as a result of inhomogeneous fragmentation of the parental molecular clump. This naturally explains the smaller current envelope mass in A2 with respect to A1 along with its molecular richness. The extremely low abundances of organic molecules in A1 with respect to those in A2 demonstrate that the dense inner regions of a young protostellar core lacking hot corino activity may be poorer in COMs than the outer protostellar envelope.

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Inner warm disk of ESO Hα 279A revealed by Na I and CO overtone emission lines

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We present analysis of near-infrared, high-resolution spectroscopy towards the Flat-spectrum YSO (Young Stellar Object) ESO Hα 279a (1.5 \( M_\odot \)) in the Serpens star forming region, at the distance of 429 pc. Using the Immersion GRating INfrared Spectrometer (IGRINS, \( R=45,000 \)), we detect emission lines originating from the accretion channel flow, jet, and inner disk. Specifically, we identify hydrogen Brackett series recombination, [Fe II], [Fe III], [Fe IV], Ca I, Na I, H\(_2\), H\(_2\)O and CO overtone emission lines. By modeling five bands of CO overtone emission lines, and the symmetric double-peaked line profile for Na I emission lines, we find that ESO Hα 279a has an actively accreting Keplerian disk. From our Keplerian disk model, we find that Na I emission lines originate between 0.04 AU and 1.00 AU, while CO overtone emission lines are from the outer part of disk, in the range between 0.22 AU and 3.00 AU. It reveals that the neutral atomic Na gas is a good tracer of the innermost region of the actively accreting disk. We derive a mass accretion rate of \((2–10) \times 10^{-7} M_\odot \text{yr}^{-1}\) from the measured Br\(\gamma\) emission luminosity of \((1.78\pm0.31) \times 10^{31} \text{erg s}^{-1}\).

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Multi-temperature mapping of dust structures throughout the Galactic Plane using the PPMAP tool with Herschel Hi-GAL data

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We describe new Hi-GAL based maps of the entire Galactic plane, obtained using continuum data in the wavelength range 70-500 \( \mu \text{m} \). These maps are derived with the PPMAP procedure, and therefore represent a significant improvement over those obtained with standard analysis techniques. Specifically they have greatly improved resolution (12 arcsec) \textit{and} in addition to more accurate integrated column densities and mean dust temperatures, they give temperature-differential column densities, i.e., separate column density maps in twelve distinct dust temperature intervals, along with the corresponding uncertainty maps. The complete set of maps is available on-line. We briefly describe PPMAP and present some illustrative examples of the results. These include (a) multi-temperature maps of the Galactic HII region W5-E, (b) the temperature decomposition of molecular cloud column-density probability distribution functions, and (c) the global variation of mean dust temperature as a function of Galactocentric distance. Amongst our findings are: (i) a strong localised temperature gradient in W5-E in a direction orthogonal to that towards the ionising star, suggesting an alternative heating source and providing possible guidance for models of the formation of the bubble complex, and (ii) the overall radial profile of dust temperature in the Galaxy shows a monotonic decrease, broadly consistent both with models of the interstellar radiation field and with previous estimates at lower resolution. However, we also find a central temperature plateau within \( \sim 6 \) kpc of the Galactic centre, outside of which is a pronounced steepening of the radial profile. This behaviour may reflect the greater proportion of molecular (as opposed to atomic) gas in the central region of the Galaxy.
The β Pictoris association low-mass members: membership assessment, rotation period distribution, and dependence on multiplicity

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Low-mass members of young stellar associations exhibit a wide spread of rotation periods. Such a spread originates from distributions of masses and initial rotation periods. However, multiplicity can also play a significant role. We investigate the role played by physical companions in shortening the primordial disc lifetime. We have compiled the most extensive list of low-mass members of the young 25-Myr β Pictoris association. We have measured the rotation periods of about all members and used updated UVWXYZ components to assess their membership. We built the rotation period distribution distinguishing between bona fide members and candidate members and according to their multiplicity status. We found that single stars and components of multiple systems in wide orbits (>80 AU) have rotation periods that exhibit a well defined sequence arising from mass distribution. All components of multiple systems in close orbits (<80 AU) have rotation periods significantly shorter than their equal-mass single counterparts. A comparison with the younger 13 Myr h Per cluster and with the older 40-Myr open clusters/stellar associations NGC2547, IC2391, Argus, and IC2602 and the 130-Myr Pleiades shows that whereas the evolution of F-G stars is well reproduced by angular momentum evolution models, this is not the case for the slow K and early-M stars. Finally, we found that the amplitude of their light curves is correlated neither with rotation nor with mass. Once single stars and wide components of multiple systems are separated from close components of multiple systems, the rotation period distributions exhibit a well defined dependence on mass that allows to make a meaningful comparison with similar distributions of either younger or older associations/clusters. Such cleaned distributions allow to use the stellar rotation period as age indicator, meaningfully for F and G type stars.

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No large population of unbound or wide-orbit Jupiter-mass planets

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Gravitational microlensing is the only method capable of exploring the entire population of free-floating planets down to Mars-mass objects, because the microlensing signal does not depend on the brightness of the lensing object. A characteristic timescale of microlensing events depends on the mass of the lens: the less massive the lens, the shorter the microlensing event. A previous analysis of 474 microlensing events found an excess of very short events (1–2 days) - more than known stellar populations would suggest - indicating the existence of a large population of unbound or wide-orbit Jupiter-mass planets (reported to be almost twice as common as main-sequence stars). These results, however, do not match predictions of planet formation theories and are in conflict with surveys of young clusters. Here we report the analysis of a six times larger sample of microlensing events discovered during the years 2010–2015. Although our survey has very high sensitivity (detection efficiency) to short-timescale (1–2 days) microlensing events, we found no excess of events with timescales in this range, with a 95% upper limit on the frequency of Jupiter-mass free-floating or wide-orbit planets of 0.25 planet per main-sequence star. We detected a few possible ultrashort-timescale events (with timescales of less than 0.5 day), which may indicate the existence of Earth- and super-Earth-mass free-floating planets, as predicted by planet-formation theories.

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The low-mass content of the massive young star cluster RCW 38
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RCW 38 is a deeply embedded young (∼1 Myr), massive star cluster located at a distance of 1.7 kpc. Twice as dense as the Orion Nebula Cluster, orders of magnitude denser than other nearby star forming regions, and rich in massive stars, RCW 38 is an ideal place to look for potential differences in brown dwarf formation efficiency as a function of environment. We present deep, high resolution adaptive optics data of the central ∼0.5 × 0.5 pc2 obtained with NACO at the Very Large Telescope. Through comparison with evolutionary models we determine masses and extinction for ∼480 candidate members, and derive the first Initial Mass Function (IMF) of the cluster extending into the substellar regime. Representing the IMF as a set of power laws in the form dN/dM ∝ M−α, we derive the slope α = 1.60 ± 0.13 for the mass range 0.5 – 20 M⊙ which is shallower than the Salpeter slope, but in agreement with results in several other young massive clusters. At the low-mass side, we find α = 0.71 ± 0.11 for masses between 0.02 and 0.5 M⊙, or α = 0.81 ± 0.08 for masses between 0.02 and 1 M⊙. Our result is in agreement with the values found in other young star-forming regions, revealing no evidence that a combination of high stellar densities and the presence of numerous massive stars affect the formation efficiency of brown dwarfs and very-low mass stars. We estimate that the Milky Way galaxy contains between 25 and 100 billion brown dwarfs (with masses > 0.03 M⊙).

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Rosette nebula globules: Seahorse giving birth to a star
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Context. The Rosette nebula is an HII region ionized mainly by the stellar cluster NGC 2244. Elephant trunks, globules, and globulettes are seen at the interface where the HII region and the surrounding molecular shell meet.

Aims. We have observed a field in the northwestern part of the Rosette nebula where we study the small globules protruding from the shell. Our aim is to measure their properties and study their star-formation history in continuation of our earlier study of the features of the region.

Methods. We imaged the region in broadband near-infrared (NIR) $JHK_s$ filters and narrowband $H_2$ 1–0 S(1), $P\beta$, and continuum filters using the SOFI camera at the ESO/NTT. The imaging was used to study the stellar population and surface brightness, create visual extinction maps, and locate star formation. Mid-infrared (MIR) Spitzer IRAC and WISE and optical NOT images were used to further study the star formation and the structure of the globules. The NIR and MIR observations indicate an outflow, which is confirmed with CO observations made with APEX.

Results. The globules have mean number densities of $\sim 4.6 \times 10^4 \text{cm}^{-3}$. $P\beta$ is seen in absorption in the cores of the globules where we measure visual extinctions of 11–16$^m$. The shell and the globules have bright rims in the observed bands. In the $K_s$ band 20 to 40% of the emission is due to fluorescent emission in the 2.12 $\mu$m $H_2$ line similar to the tiny dense globulettes we studied earlier in a nearby region. We identify several stellar NIR excess candidates and four of them are also detected in the Spitzer IRAC 8.0 $\mu$m image and studied further. We find an outflow with a cavity wall bright in the 2.124 $\mu$m $H_2$ line and at 8.0 $\mu$m in one of the globules. The outflow originates from a Class I young stellar object (YSO) embedded deep inside the globule. An H$\alpha$ image suggests the YSO drives a possible parsec-scale outflow. Despite the morphology of the globule, the outflow does not seem to run inside the dusty fingers extending from the main globule body.

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Large-scale Map of Millimeter-wavelength Hydrogen Radio Recombination Lines around a Young Massive Star Cluster


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$^{10}$ This work is dedicated to the memory of C. M. Walmsley, who made many pioneering contributions to using recombination lines as a diagnostic of the interstellar medium.

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We report the first map of large-scale (10 pc in length) emission of millimeter-wavelength hydrogen recombination lines (mm-RRLs) toward the giant H II region around the W43-Main young massive star cluster (YMC). Our mm-RRL data come from the IRAM 30 m telescope and are analyzed together with radio continuum and cm-RRL data from the Karl G. Jansky Very Large Array and HCO+ 10 line emission data from the IRAM 30 m. The mm-RRLs reveal an expanding wind-blown ionized gas shell with an electron density 70-1500 cm$^{-3}$ driven by the WR/OB cluster, which
produces a total Lyα photon flux of $1.5 \times 10^{50}$ s$^{-1}$. This shell is interacting with the dense neutral molecular gas in the W43-Main dense cloud. Combining the high spectral and angular resolution mm-RRL and cm-RRL cubes, we derive the two-dimensional relative distributions of dynamical and pressure broadening of the ionized gas emission and find that the RRL line shapes are dominated by pressure broadening (4-55 km s$^{-1}$) near the YMC and by dynamical broadening (8-36 km s$^{-1}$) near the shell’s edge. Ionized gas clumps hosting ultra-compact H ii regions found at the edge of the shell suggest that large-scale ionized gas motion triggers the formation of new star generation near the periphery of the shell.

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The JCMT BISTRO Survey: The magnetic field strength in the Orion A filament

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We determine the magnetic field strength in the OMC 1 region of the Orion A filament via a new implementation of the Chandrasekhar-Fermi method using observations performed as part of the James Clerk Maxwell Telescope (JCMT) B-Fields In Star-Forming Region Observations (BISTRO) survey with the POL-2 instrument. We combine BISTRO data with archival SCUBA-2 and HARP observations to find a plane-of-sky magnetic field strength in OMC 1 of $B_{\text{pos}} = 6.6 \pm 4.7$ mG, where $\delta B_{\text{pos}} = 4.7$ mG represents a predominantly systematic uncertainty. We develop a
new method for measuring angular dispersion, analogous to unsharp masking. We find a magnetic energy density of \(\sim 1.7 \times 10^{-7}\) J m\(^{-3}\) in OMC 1, comparable both to the gravitational potential energy density of OMC 1 (\(\sim 10^{-7}\) J m\(^{-3}\)), and to the energy density in the Orion BN/KL outflow (\(\sim 10^{-7}\) J m\(^{-3}\)). We find that neither the Alfvén velocity in OMC 1 nor the velocity of the super-Alfvénic outflow ejecta is sufficiently large for the BN/KL outflow to have caused large-scale distortion of the local magnetic field in the \(\sim 500\)-year lifetime of the outflow. Hence, we propose that the hour-glass field morphology in OMC 1 is caused by the distortion of a primordial cylindrically-symmetric magnetic field by the gravitational fragmentation of the filament and/or the gravitational interaction of the BN/KL and S clumps. We find that OMC 1 is currently in or near magnetically-supported equilibrium, and that the current large-scale morphology of the BN/KL outflow is regulated by the geometry of the magnetic field in OMC 1, and not vice versa.

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Sensitivity analysis of grain surface chemistry to binding energies of ice species

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Advanced telescopes, such as ALMA and JWST, are likely to show that the chemical universe may be even more complex than currently observed, requiring astrochemical modelers to improve their models to account for the impact of new data. However, essential input information for gas-grain models, such as binding energies of molecules to the surface, have been derived experimentally only for a handful of species, leaving hundreds of species with highly uncertain estimates. We present in this paper a systematic study of the effect of uncertainties in the binding energies on an astrochemical two-phase model of a dark molecular cloud, using the rate equations approach. A list of recommended binding energy values based on a literature search of published data is presented. Thousands of simulations of dark cloud models were run, and in each simulation a value for the binding energy of hundreds of species was randomly chosen from a normal distribution. Our results show that the binding energy of H\(_2\) is critical for the surface chemistry. For high binding energy, H\(_2\) freezes out on the grain forming an H\(_2\) ice. This is not physically realistic and we suggest a change in the rate equations. The abundance ranges found are in reasonable agreement with astronomical ice observations. Pearson correlation coefficients revealed that the binding energy of HCO, HNO, CH\(_2\), and C correlate most strongly with the abundance of dominant ice species. Finally, the formation route of complex organic molecules was found to be sensitive to the branching ratios of H\(_2\)CO hydrogenation.

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Dust Density Distribution and Imaging Analysis of Different Ice Lines in Protoplanetary Disks

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Recent high angular resolution observations of protoplanetary disks at different wavelengths have revealed several kinds of structures, including multiple bright and dark rings. Embedded planets are the most used explanation for such structures, but there are alternative models capable to shape the dust in rings as it has been observed. We
assume a disk around a Herbig star and investigate the effect that ice lines have on the dust evolution, following the growth, fragmentation and dynamics of multiple dust size particles, covering from $1 \mu m$ to $2 m$ sized objects. We use simplified prescriptions of the fragmentation velocity threshold, which is assumed to change radially at the location of one, two, or three ice lines. We assume changes at the radial location of main volatiles, specifically $H_2O$, $CO_2$, and $NH_3$. Radiative transfer calculations are done using the resulting dust density distributions in order to compare with current multi-wavelength observations. We find that the structures in the dust density profiles and radial intensities at different wavelengths strongly depend on the disk viscosity. A clear gap of emission can be formed between ice lines and be surrounded by ring-like structures, in particular between the $H_2O$ and $CO_2$ (or $CO$). The gaps are expected to be shallower and narrower at millimeter emission than at near-infrared, opposite to model predictions of particle trapping. In our models, the total gas surface density is not expected to show strong variations, in contrast to other gap-forming scenarios such as embedded giant planets or radial variations of the disk viscosity.

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Chandra X-ray observation of the young stellar cluster NGC 3293 in the Carina Nebula Complex
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Context. NGC 3293 is a young stellar cluster at the northwestern periphery of the Carina Nebula Complex that has remained poorly explored until now.

Aims. We characterize the stellar population of NGC 3293 in order to evaluate key parameters of the cluster population such as the age and the mass function, and to test claims of an abnormal IMF and a deficit of $M \leq 2.5 M_\odot$ stars.

Methods. We performed a deep (70 ksec) X-ray observation of NGC 3293 with Chandra and detected 1026 individual X-ray point sources. These X-ray data directly probe the low-mass ($M \leq 2 M_\odot$) stellar population by means of the strong X-ray emission of young low-mass stars. We identify counterparts for 74% of the X-ray sources in our deep near-infrared images.

Results. Our data clearly show that NGC 3293 hosts a large population of $\approx$ solar-mass stars, refuting claims of a lack of $M \leq 2.5 M_\odot$ stars. The analysis of the color magnitude diagram suggests an age of $\sim 8 - 10$ Myr for the low-mass population of the cluster. There are at least 511 X-ray detected stars with color magnitude positions that are consistent with young stellar members within 7 arcmin of the cluster center. The number ratio of X-ray detected stars in the $[1 - 2] M_\odot$ range versus the $M \geq 5 M_\odot$ stars (known from optical spectroscopy) is consistent with the expectation from a normal field initial mass function. Most of the early B-type stars and $\approx 20\%$ of the later B-type stars are detected as X-ray sources.

Conclusions. Our data shows that NGC 3293 is one of the most populous stellar clusters in the entire Carina Nebula Complex (very similar to Tr 16 and Tr 15; only Tr 14 is more populous). The cluster probably harbored several O-type stars, whose supernova explosions may have had an important impact on the early evolution of the Carina Nebula Complex.

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Proper motions of the HH 1 jet

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We describe a new method for determining proper motions of extended objects, and a pipeline developed for the application of this method. We then apply this method to an analysis of four epochs of [S II] HST images of the HH 1 jet (covering a period of $\sim 20$ yr). We determine the proper motions of the knots along the jet, and make a reconstruction of the past ejection velocity time-variability (assuming ballistic knot motions). This reconstruction shows an “acceleration” of the ejection velocities of the jet knots, with higher velocities at more recent times. This acceleration will result in an eventual merging of the knots in $\sim 450$ yr and at a distance of $\sim 80''$ from the outflow source, close to the present-day position of HH 1.

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http://bigbang.nucleares.unam.mx/astroplasmas/
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### A model for a photoionized, conical jet from a young, massive star

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We consider a conical jet from a massive, young star, which also powers a compact H II region. The high density at the base of the jet traps the stellar, ionizing radiation, so that the jet beam is neutral (at larger distances). This neutral beam then becomes progressively photoionized by the diffuse, ionizing radiation field emitted by the surrounding H II region. We derive a simple, analytic model for this flow, and use it to calculate the contrast between the free-free emission of the jet and the background H II region. We find that for appropriate parameters, the jet is brighter by $\sim 20\%$, which should be relatively straightforward to detect in interferometric maps of regions around massive, young stars.

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### VLA observations of the disk around the young brown dwarf 2MASSS J044427+2512

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We present multi-wavelength radio observations obtained with the VLA of the protoplanetary disk surrounding the young brown dwarf 2MASSS J04442713+2512164 (2M0444) in the Taurus star forming region. 2M0444 is the brightest known brown dwarf disk at millimeter wavelengths, making this an ideal target to probe radio emission from a young brown dwarf. Thermal emission from dust in the disk is detected at 6.8 and 9.1 mm, whereas the 1.36 cm measured flux is dominated by ionized gas emission. We combine these data with previous observations at shorter sub-mm and...
mm wavelengths to test the predictions of dust evolution models in gas-rich disks after adapting their parameters to the case of 2M0444. These models show that the radial drift mechanism affecting solids in a gaseous environment has to be either completely made inefficient, or significantly slowed down by very strong gas pressure bumps in order to explain the presence of mm/cm-sized grains in the outer regions of the 2M0444 disk. We also discuss the possible mechanisms for the origin of the ionized gas emission detected at 1.36 cm. The inferred radio luminosity for this emission is in line with the relation between radio and bolometric luminosity valid for for more massive and luminous young stellar objects, and extrapolated down to the very low luminosity of the 2M0444 brown dwarf.

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The ionising effect of low energy cosmic rays from a class II object on its protoplanetary disk

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We investigate the ionising effect of low energy cosmic rays (CRs) from a young star on its protoplanetary disk (PPD). We consider specifically the effect of $\sim 3$ GeV protons injected at the inner edge of the PPD. An increase in the ionisation fraction as a result of these CRs could allow the magnetorotational instability to operate in otherwise magnetically dead regions of the disk. For the typical values assumed we find an ionisation rate of $\zeta_{\text{CR}} \sim 10^{-17}$ s$^{-1}$ at 1 au.

The transport equation is solved by treating the propagation of the CRs as diffusive. We find for increasing diffusion coefficients the CRs penetrate further in the PPD, while varying the mass density profile of the disk is found to have little effect. We investigate the effect of an energy spectrum of CRs. The influence of a disk wind is examined by including an advective term. For advective wind speeds between 1 – 100 km s$^{-1}$ diffusion dominates at all radii considered here (out to 10 au) for reasonable diffusion coefficients.

Overall, we find that low energy CRs can significantly ionise the midplane of PPDs out to $\sim 1$ au. By increasing the luminosity or energy of the CRs, within plausible limits, their radial influence could increase to $\sim 2$ au at the midplane but it remains challenging to significantly ionise the midplane further out.

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Near-infrared time-series photometry in the field of Cygnus OB2 association I - Rotational scenario for candidate members

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Context: In recent decades, the picture of early pre-main sequence stellar rotational evolution has been constrained by studies targeting different regions at a variety of ages with respect to young star formation. Observational studies suggest a dependence of rotation with mass, and for some mass ranges a connection between rotation and the presence of a circumstellar disk. The role of environmental conditions on the rotational regulation, however, has still not been fully explored.

Aims: We investigate the rotational properties of candidate members of the young massive association Cygnus OB2. By evaluating their rotational properties, we address questions regarding the effect of environment properties on PMS
rotational evolution.

Methods: We studied JHK-band variability in 5083 candidate members (24% of them are disk-bearing stars). We selected variable stars with the Stetson variability index and performed the period search with the Lomb-Scargle periodogram for periods between 0.83-45 days. Period detections were verified using false alarm probability levels, Saunders statistics, the string and rope length method, and visual verification of folded light curves.

Results: We identified 1224 periodic variable stars (24% of the candidate member sample, 8% of the disk-bearing sample, and 28% of the non-disk-bearing sample). Monte Carlo simulations were performed in order to evaluate completeness and contamination of the periodic sample, out of which 894 measured periods were considered reliable. Our study was considered reasonably complete for periods between 2 and 30 days.

Conclusions: The general scenario for the rotational evolution of young stars seen in other regions is confirmed by Cygnus OB2 period distributions with disc-bearing stars rotating on average more slowly than non-disk-bearing stars. A mass-rotation dependence was also verified, but as in NGC 6530, very low mass stars ($M \leq 0.4M_\odot$) are rotating on average slower than higher mass stars ($0.4M_\odot < M \leq 1.4M_\odot$). We observed an excess of slow rotators among the lower mass population. The disk and mass-rotation connection was also analyzed by taking into account the incident UV radiation arising from O stars in the association. Results compatible with the disk-locking scenario were verified for stars with low UV incidence, but no statistical significant relation between rotation and disk presence was verified for stars with high UV incidence suggesting that massive stars can have an important role in regulating the rotation of nearby low mass stars.

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Signatures of rocky planet engulfment in HAT-P-4. Implications for chemical tagging studies

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Aims. To explore the possible chemical signature of planet formation in the binary system HAT-P-4, by studying abundance vs condensation temperature $T_c$ trends. The star HAT-P-4 hosts a planet detected by transits while its stellar companion does not have any detected planet. We also study the Lithium content, which could shed light on the problem of Li depletion in exoplanet host stars.

Conclusions. The exoplanet host star HAT-P-4 is found to be $\sim 0.1$ dex more metal rich than its companion, which is one of the highest differences in metallicity observed in similar systems. This could have important implications for chemical tagging studies, disentangling groups of stars with a common origin. We rule out a possible peculiar composition for each star as $\lambda$ Boo, $\delta$ Scuti or a Blue Straggler. The star HAT-P-4 is enhanced in refractory elements relative to volatile when compared to its stellar companion. Notably, the Lithium abundance in HAT-P-4 is greater than in its companion by $\sim 0.3$ dex, which is contrary to the model that explains the Lithium depletion by the presence of planets. We propose a scenario where, at the time of planet formation, the star HAT-P-4 locked the inner refractory material in planetesimals and rocky planets, and formed the outer gas giant planet at a greater distance. The refractories were then accreted onto the star, possibly due to the migration of the giant planet. This explains the higher metallicity, the higher Lithium content, and the negative $T_c$ trend detected. A similar scenario was recently proposed for the solar twin star HIP 68468, which is in some aspects similar to HAT-P-4. We estimate a mass of at least $M_{\text{rock}} \sim 10 M_{\text{Earth}}$ locked in refractory material in order to reproduce the observed $T_c$ trends and metallicity.

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Expelled grains from an unseen parent body around AU Mic

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Recent observations of the debris disk of AU Mic have revealed asymmetric, fast outward-moving arch-like structures above the disk midplane. No model can readily explain the characteristics of these features. We present a model aiming to reproduce the dynamics of these structures, more specifically their high projected speeds and their apparent position. We test the hypothesis of dust emitted by a point source and then expelled from the system by the strong stellar wind of this young, M-type star. In this model, we make the assumption that the dust grains follow the same dynamics as the structures. We perform numerical simulations of test particle trajectories to explore the available parameter space, in particular the radial location \( R_0 \) of the dust producing parent body and the size of the dust grains as parameterized by \( \beta \) (ratio of stellar wind and radiation pressure forces over gravitation). We consider both the case of a static and an orbiting parent body. We find that, for all considered scenarios, there is always a set of \((R_0,\beta)\) parameters able to fit the observed features. The common characteristics of these solutions is that they all require a high value of \( \beta \), of around 6. This means that the star is probably very active and the grains composing the structures are sub-micronic, in order to reach such high \( \beta \) values. As for the location of the hypothetical parent body, we constrain it to lie around 8 au (orbiting case) or 28 au (static case). We show that the scenario of sequential dust releases by an unseen, punctual parent body is able to explain the radial behavior of the observed structures. We predict the evolution of the structures to help future observations to discriminate between the different parent body configurations that have been considered. We expect new structures to appear on the northwest side of the disk in the coming years.

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**Species-to-species rate coefficients for the \( \text{H}_3^+ + \text{H}_2 \) reacting system**

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**Aims.** We study whether or not rotational excitation can make a large difference to chemical models of the abundances of the \( \text{H}_3^+ \) isotopologs, including spin states, in physical conditions corresponding to starless cores and protostellar envelopes.

**Methods.** We developed a new rate coefficient set for the chemistry of the \( \text{H}_3^+ \) isotopologs, allowing for rotational excitation, using previously published state-to-state rate coefficients. These new so-called species-to-species rate coefficients are compared with previously-used ground-state-to-species rate coefficients by calculating chemical evolution in variable physical conditions using a pseudo-time-dependent chemical code.

**Results.** We find that the new species-to-species model produces different results to the ground state-to-species model at high density and toward increasing temperatures (\( T > 10 \text{ K} \)). The most prominent difference is that the species-to-species model predicts a lower \( \text{H}_3^+ \) deuteration degree at high density owing to an increase of the rate coefficients of endothermic reactions that tend to decrease deuteration. For example at 20 K, the ground-state-to-species model overestimates the abundance of \( \text{H}_2 \text{D}^+ \) by a factor of about two, while the abundance of \( \text{D}_2 \text{H}^+ \) can differ by up to an order of magnitude between the models. The spin-state abundance ratios of the various \( \text{H}_3^+ \) isotopologs are also affected, and the new model better reproduces recent observations of the abundances of ortho and para \( \text{H}_2 \text{D}^+ \) and \( \text{D}_2 \text{H}^+ \). The main caveat is that the applicability regime of the new rate coefficients depends on the critical densities of the various rotational transitions which vary with the abundances of the species and the temperature in dense clouds.

**Conclusions.** The difference in the abundances of the \( \text{H}_3^+ \) isotopologs predicted by the species-to-species and ground state-to-species models is negligible at 10 K corresponding to physical conditions in starless cores, but inclusion of the excited states is very important in studies of deuteration at higher temperatures, for example in protostellar envelopes. The species-to-species rate coefficients provide a more realistic approach to the chemistry of the \( \text{H}_3^+ \) isotopologs than the ground-state-to-species rate coefficients do, and so the former should be adopted in chemical models describing the chemistry of the \( \text{H}_3^+ + \text{H}_2 \) reacting system.

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The observed chemical structure of L1544
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Prior to star formation, pre-stellar cores accumulate matter towards the centre. As a consequence, their central density increases while the temperature decreases. Understanding the evolution of the chemistry and physics in this early phase is crucial to study the processes governing the formation of a star. We aim at studying the chemical differentiation of a prototypical pre-stellar core, L1544, by detailed molecular maps. In contrast with single pointing observations, we performed a deep study on the dependencies of chemistry on physical and external conditions. We present the emission maps of 39 different molecular transitions belonging to 22 different molecules in the central 6.25 arcmin² of L1544. We classified our sample in five families, depending on the location of their emission peaks within the core. Furthermore, to systematically study the correlations among different molecules, we have performed the principal component analysis (PCA) on the integrated emission maps. The PCA allows us to reduce the amount of variables in our dataset. Finally, we compare the maps of the first three principal components with the H$_2$ column density map, and the $T_{dust}$ map of the core. The results of our qualitative analysis is the classification of the molecules in our dataset in the following groups: (i) the c-C$_3$H$_2$ family (carbon chain molecules like C$_3$H and CCS), (ii) the dust peak family (nitrogen-bearing species like N$_2$H$^+$), (iii) the methanol peak family (oxygen-bearing molecules like methanol, SO and SO$_2$), (iv) the HNCO peak family (HNCO, propyne and its deuterated isotopologues). Only HC$^{18}$O$^+$ and $^{13}$CS do not belong to any of the above mentioned groups. The principal component maps allow us to confirm the (anti-)correlations among different families that were described in a first qualitative analysis, but also points out the correlation that could not be inferred before. For example, the molecules belonging to the dust peak and the HNCO peak families correlate in the third principal component map, hinting on a chemical/physical correlation. The principal component analysis has shown to be a powerful tool to retrieve information about the correlation of different molecular species in L1544, and their dependence on physical parameters previously studied in the core.

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Alignment Between Protostellar Outflows and Filamentary Structure
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We present new Submillimeter Array (SMA) observations of CO(2–1) outflows toward young, embedded protostars in the Perseus molecular cloud as part of the Mass Assembly of Stellar Systems and their Evolution with the SMA (MASSES) survey. For 57 Perseus protostars, we characterize the orientation of the outflow angles and compare them with the orientation of the local filaments as derived from Herschel observations. We find that the relative angles between outflows and filaments are inconsistent with purely parallel or purely perpendicular distributions. Instead, the observed distribution of outflow-filament angles are more consistent with either randomly aligned angles or a mix of projected parallel and perpendicular angles. A mix of parallel and perpendicular angles requires perpendicular alignment to be more common by a factor of \( \sim 3 \). Our results show that the observed distributions probably hold regardless of the protostar's multiplicity, age, or the host core's opacity. These observations indicate that the angular momentum axis of a protostar may be independent of the large-scale structure. We discuss the significance of independent protostellar rotation axes in the general picture of filament-based star formation.

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\(^{13}\)C isotopic fractionation of HC\(_3\)N in two starless cores: L1521B and L134N (L183)

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We observed the \( J = 5 \rightarrow 4 \) rotational lines of the normal species and three \(^{13}\)C isotopologues of HC\(_3\)N at the 45 GHz band toward two low-mass starless cores, L1521B and L134N (L183), using the Nobeyama 45 m radio telescope in order to study the main formation pathways of HC\(_3\)N in each core. The abundance ratios of the three \(^{13}\)C isotopologues in L1521B are derived to be \([\text{H}^{13}\text{CCCN}] : [\text{HC}^{13}\text{CCN}] : [\text{HCC}^{13}\text{CN}] = 0.98 (0.14) : 1.00 : 1.52 (0.16) \) (1 sigma). The fractionation pattern is consistent with that at the cyanopolyne peak in Taurus Molecular Cloud-1. This fractionation pattern suggests that the main formation pathway of HC\(_3\)N is the neutral-neutral reaction between C\(_2\)H\(_2\) and CN. On the other hand, their abundance ratios in L134N are found to be \([\text{H}^{13}\text{CCCN}] : [\text{HC}^{13}\text{CCN}] : [\text{HCC}^{13}\text{CN}] = 1.5 (0.2) : 1.0 : 2.1 (0.4) \) (1 sigma), which are different from those in L1521B. From this fractionation pattern, we propose that the reaction between HNC and CCH is a possible main formation pathway of HC\(_3\)N in L134N. We find out that the main formation pathways of the same molecule are not common even in the similar physical conditions. We discuss the possible factors to make a difference in fractionation pattern between L134N and L1521B/TMC-1.

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Physical properties of dusty protoplanetary disks in Lupus: evidence for viscous evolution?

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The formation of planets strongly depends on the total amount as well as on the spatial distribution of solids in protoplanetary disks. Thanks to the improvements in resolution and sensitivity provided by ALMA, measurements of the surface density of mm-sized grains are now possible on large samples of disks. Such measurements provide statistical constraints that can be used to inform our understanding of the initial conditions of planet formation. We analyze spatially resolved observations of 36 protoplanetary disks in the Lupus star forming complex from our ALMA survey at 890 µm, aiming to determine physical properties such as the dust surface density, the disk mass and size and to provide a constraint on the temperature profile. We fit the observations directly in the uv-plane using a two-layer disk model that computes the 890 µm emission by solving the energy balance at each disk radius. For 22 out of 36 protoplanetary disks we derive robust estimates of their physical properties. The sample covers stellar masses between ∼0.1 and ∼2 M⊙, and we find no trend between the average disk temperatures and the stellar parameters. We find, instead, a correlation between the integrated sub-mm flux (a proxy for the disk mass) and the exponential cut-off radii (a proxy of the disk size) of the Lupus disks. Comparing these results with observations at similar angular resolution of Taurus-Auriga/Ophiuchus disks found in literature and scaling them to the same distance, we observe that the Lupus disks are generally fainter and larger at a high level of statistical significance. Considering the 1–2 Myr age difference between these regions, it is possible to tentatively explain the offset in the disk mass/disk size relation with viscous spreading, however with the current measurements other mechanisms cannot be ruled out. Accepted by A&A

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Dust properties of the cometary globule Barnard 207 (LDN 1489)
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Barnard 207 (B207, LDN 1489, LBN 777), also known as the Vulture Head nebula, is a cometary globule in the Taurus-Auriga-Perseus molecular cloud region. B207 is known to host a Class I protostar, IRAS 04016+2610, located at a projected distance of ∼8,400 au from the dense core centre. Using imaging and photometry over a wide wavelength range, from UV to sub-mm, we study the physical properties of B207 and the dust grains contained within. The core density, temperature, and mass are typical of other globules found in the Milky Way interstellar medium (ISM). The increase in the dust albedo with increasing optical wavelengths, along with the detection of coreshine in the near infrared, indicates the presence of larger dust grains in B207. The measured optical, near-, mid- and far-infrared intensities are in agreement with the CMM+AMM and CMM+AMMI dust grain type of The Heterogeneous dust Evolution Model for Interstellar Solids (THEMIS), suggesting mantle formation on the dust grains throughout the globule. We investigate the possibility of turbulence being responsible for diffusing dust grains from the central core to external outer layers of B207. However, in situ formation of large dust grains cannot be excluded. Accepted by A&A

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Constraining accretion signatures of exoplanets in the TW Hya transitional disk
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We present a near-infrared direct imaging search for accretion signatures of possible protoplanets around the young stellar object (YSO) TW Hya, a multi-ring disk exhibiting evidence of planet formation. The Pa$\beta$ line (1.282 $\mu$m) is an indication of accretion onto a protoplanet, and its intensity is much higher than that of blackbody radiation from the protoplanet. We focused on the Pa$\beta$ line and performed Keck/OSIRIS spectroscopic observations. Although spectral differential imaging (SDI) reduction detected no accretion signatures, the results of the present study allowed us to set $5\sigma$ detection limits for Pa$\beta$ emission of $5.8 \times 10^{-18}$ and $1.5 \times 10^{-18}$ erg s$^{-1}$ cm$^{-2}$ at 0$''$.4 and 1$''$.6, respectively. We considered the mass of potential planets using theoretical simulations of circumplanetary disks and hydrogen emission. The resulting masses were $1.45 \pm 0.04$ $M_J$ and $2.29^{+0.03}_{-0.04}$ $M_J$ at 25 and 95 AU, respectively, which agree with the detection limits obtained from previous broadband imaging. The detection limits should allow the identification of protoplanets as small as $\sim 1$ $M_J$, which may assist in direct imaging searches around faint YSOs for which extreme adaptive optics instruments are unavailable.

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Star formation in evolving molecular clouds

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Molecular clouds are the principle stellar nurseries of our universe, keeping them in the focus of both observational and theoretical studies. From observations, some of the key properties of molecular clouds are well known but many questions regarding their evolution and star formation activity remain open. While numerical simulations feature a large number and complexity of involved physical processes, this plenty of effects may hide the fundamentals that determine the evolution of molecular clouds and enable the formation of stars. Purely analytical models, on the other hand, tend to suffer from rough approximations or a lack of completeness, limiting their predictive power. In this paper, we present a model that incorporates central concepts of astrophysics as well as reliable results from recent simulations of molecular clouds and their evolutionary paths. Based on that, we construct a self-consistent semi-analytical framework that describes the formation, evolution and star formation activity of molecular clouds, including a number of feedback effects to account for the complex processes inside those objects. The final equation system is solved numerically but at much lower computational expense than, e.g., hydrodynamical descriptions of comparable systems. The model presented in this paper agrees well with a broad range of observational results, showing that molecular cloud evolution can be understood as an interplay between accretion, global collapse, star formation and stellar feedback.

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Molecular-Cloud-Scale Chemical Composition I: Mapping Spectral Line Survey toward W51 in the 3 mm Band

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We have conducted a mapping spectral line survey toward the Galactic giant molecular cloud W51 in the 3 mm band with the Mopra 22 m telescope in order to study an averaged chemical composition of the gas extended over a molecular cloud scale in our Galaxy. We have observed the area of $25' \times 30'$, which corresponds to 39 pc $\times$ 47 pc. The frequency ranges of the observation are 85.1–101.1 GHz and 107.0–114.9 GHz. In the spectrum spatially averaged over the observed area, spectral lines of 12 molecular species and 4 additional isotopologues are identified. An intensity pattern of the spatially-averaged spectrum is found to be similar to that of the spiral arm in the external galaxy M51, indicating that these two sources have similar chemical compositions. The observed area has been classified into 5 sub-regions according to the integrated intensity of $^{13}$CO($J = 1-0$) ($I_{^{13}CO}$), and contributions of the fluxes of 11 molecular lines from each sub-region to the averaged spectrum have been evaluated. For most of molecular species, 50% or more of the flux come from the sub-regions with $I_{^{13}CO}$ from 25 K km s$^{-1}$ to 100 K km s$^{-1}$, which does not involve active star forming regions. Therefore, the molecular-cloud-scale spectrum observed in the 3 mm band hardly represents the chemical composition of star forming cores, but mainly represents the chemical composition of an extended quiescent molecular gas. The present result constitutes a sound base for interpreting the spectra of external galaxies at a resolution of a molecular cloud scale ($\sim$10 pc) or larger.

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Scattering-Produced (Sub)millimeter Polarization in Inclined Disks: Optical Depth Effects, Near-Far Side Asymmetry, and Dust Settling

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Disk polarization at (sub)millimeter wavelengths is being revolutionized by ALMA observationally, but its origin remains uncertain. Dust scattering was recently recognized as a potential contributor to polarization, although its basic properties have yet to be thoroughly explored. Here, we quantify the effects of optical depth on the scattering-induced polarization in inclined disks through a combination of analytical illustration, approximate semi-analytical modeling using formal solution to the radiative transfer equation, and Monte Carlo simulations. We find that the near-side of the disk is significantly brighter in polarized intensity than the far-side, provided that the disk is optically thick and that the scattering grains have yet to settle to the midplane. This asymmetry is the consequence of a simple geometric effect: the near-side of the disk surface is viewed more edge-on than the far-side. It is a robust signature that may be used to distinguish the scattering-induced polarization from that by other mechanisms, such as aligned grains. The asymmetry is weaker for a geometrically thinner dust disk. As such, it opens an exciting new window on dust settling. We find anecdotal evidence from dust continuum imaging of edge-on disks that large grains are not yet settled in the youngest (Class 0) disks, but become more so in older disks. This trend is corroborated by the polarization data in inclined disks showing that younger disks have more pronounced near-far side asymmetry and thus less grain settling. If confirmed, the trend would have far-reaching implications for grain evolution and, ultimately, the formation of planetesimals and planets.
Mass-size scaling $M \sim r^{1.67}$ of massive star-forming clumps - evidences of turbulence-regulated gravitational collapse

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We study the fragmentation of eight massive clumps using data from ATLASGAL 870 µm, SCUBA 850 and 450 µm, PdBI 1.3 and 3.5 mm, and probe the fragmentation from 1 pc to 0.01 pc scale. We find that the masses and the sizes of our objects follow $M \sim r^{1.68 \pm 0.05}$. The results are in agreements with the predictions of Li (2017) where $M \sim r^{5/3}$. Inside each object, the densest structures seem to be centrally condensed, with $\rho(r) \sim r^{-2}$. Our observational results support a scenario where molecular gas in the Milky Way is supported by a turbulence characterized by a constant energy dissipation rate, and gas fragments like clumps and cores are structures which are massive enough to be dynamically detached from the ambient medium.

Abstracts of recently accepted major reviews

Planet formation and disk-planet interactions

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This review is based on lectures given at the 45th Saas-Fee Advanced Course 'From Protoplanetary Disks to Planet Formation' held in March 2015 in Les Diablerets, Switzerland. Starting with an overview of the main characteristics of the Solar System and extrasolar planets, we describe the planet formation process in terms of the sequential accretion scenario. First the growth processes of dust particles to planetesimals and subsequently to terrestrial planets or planetary cores are presented. This is followed by the formation process of the giant planets either by core accretion or gravitational instability. Finally, the dynamical evolution of the orbital elements as driven by disk-planet interaction and the overall evolution of multi-object systems is presented.

Lecture Notes of the 45th Saas-Fee Advanced Course
http://arxiv.org/pdf/1707.07148
Disks of gas and dust around forming stars – circumstellar disks – last only a few million years. This is a very small fraction of the entire lifetime of Sun-like stars, several billion years. Nevertheless, by the time circumstellar disks dissipate stars complete building up their masses, giant planets finish accreting gas, and terrestrial bodies are nearly fully grown and ready for their final assembly to become planets. Understanding the evolution of circumstellar disks are thus crucial in many contexts. Using numerical simulations as the primary tool, my thesis has focused on the studies of various physical processes that can occur throughout the lifetime of circumstellar disks, from their formation to dispersal. Chapters 2, 3, and 4 emphasize the importance of early evolution, during which time a forming star-disk system obtains mass from its natal cloud: the infall phase. In Chapter 2 and 3, I have modeled episodic outbursts of accretion in protostellar systems resulting from disk instabilities – gravitational instability and magnetorotational instability. I showed that outbursts occur preferentially during the infall phase, because the mass addition provides more favorable conditions for gravitational instability to initiate the outburst cycle, and that forming stars build up a significant fraction of their masses through repeated short-lived, episodic outbursts. The infall phase can also be important for the formation of planets. Recent ALMA observations revealed sets of bright and dark rings in circumstellar disks of young, forming stars, potentially indicating early formation of planets. In Chapter 4, I showed that infall streams can create radial pressure bumps near the outer edge of the mass landing on the disk, from which vortices can form, collecting solid particles very efficiently to make initial seeds of planets. The next three chapters highlight the role of planets in setting the observational appearance and the evolution of circumstellar disks. When a planet forms in a disk, the gravitational interaction between the planet and disk can create structures, such as spiral arms and gaps. In Chapter 5, I compared the disk structures formed by planetary companions in numerical simulations with the observed structures in the disk surrounding an 8 Myr-old Herbig Ae star SAO 206462. Based on the experiments, I made predictions for the mass and position of a currently unrevealed planet, which can help guide future observations to search for more conclusive evidence for the existence of a planetary companion in the system. In Chapter 6, I showed for the first time in global simulation domains that spiral waves, driven for instance by planets or gravitational instability, can be unstable due to resonant interactions with inertial modes, breaking into turbulence. In Chapter 7, I showed that the spiral wave instability operates on the waves launched by planets and that the resulting turbulence can significantly stir up solid particles from the disk midplane. The stirring of solid particles can have influences on the observation appearance of the parent disk and on the subsequent assembly of planetary bodies in the disk. Finally, in Chapter 8, I investigated the dispersal of circumstellar disks via photoevaporative winds, finding that the photoevaporative loss alone, coupled with a range of initial angular momenta of protostellar clouds, can explain the observed decline of the disk frequency with increasing age. The findings and future possibilities are summarized in Chapter 9.
Variability and Rotation of Young Low Mass Stars: The case of the Cygnus OB2 Association

Julia Roquette

Thesis work conducted at: Physics Department of the Federal University of Minas Gerais (UFMG), Brazil, with one year as a visiting PhD student at the Institute of Planetology and Astrophysics of Grenoble (IPAG), France

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Photometric variability is one of the main characteristics of young stellar objects and explore its particularities in different wavelengths may provide insights on the ongoing physical processes at work in such objects. The most common source of photometric variability in young stars is the brightness modulation, caused by the rotation of a spotted stellar surface. This type of variability allows to measure rotation periods in young stars.

In the last decades, the early evolution of pre-main sequence stellar rotational picture has been constrained by studies targeting different young regions at a variety of ages. Observational studies suggest a dependence of rotation with mass, and for some mass ranges a connection between rotation and the presence of a circumstellar disc. Not still fully explored, though, is the role of environmental conditions on the stellar rotational regulation.

In this thesis, we explored the occurrence and main characteristics of near-infrared variability for young stars of the massive OB association Cygnus OB2, which is 1.4 kpc away from the Sun. For objects with periodic variability that could be associated with stellar rotation, we investigated the rotational properties of Cygnus OB2 members. For the sample of rotational periods evaluated, we addressed questions regarding the effect of environment properties on the pre-main sequence rotational evolution.

We investigated JHK-band variability of 5083 candidate members (24% of which are disc-bearing stars), using data observed with the wide-field camera (WFCAM) of the UK Infrared Telescope (UKIRT) on Mauna Kea, Hawai. A total of 112 nights were observed, spanning 217 days. The sample studied is spread over a field of 0.78 squared degrees.

The selection of variable stars was done by using Stetson variability index, and 60% of the stars in the sample were found to be variable according to this criterion. We investigated the light-curve morphology, and the variations in the colour-colour and colour-magnitude diagrams for JHK-bands, and when the variability was highly correlated in different bands and colours, the slopes produced by the variations inside such diagrams were estimated. These slopes were compared to the slopes expected from the models explaining physical mechanisms responsible by the variability in young stars, and the causes of variability were investigated.

Period search was performed using Lomb-Scargle periodogram for periods between 0.83-45 days. Period detection quality was verified by using False Alarm Probability levels, the Saunders statistics, string/rope length method, and visual verification of folded light curves. We identified 1224 periodic variable stars. Monte Carlo simulations were performed in order to evaluate completeness and contamination of the periodic sample, out of which 894 measured periods were considered as reliable. Our study was considered reasonably complete for periods between 2 and 30 days.

The general scenario for the rotational evolution of young stars seen in other regions is confirmed by Cygnus OB2 period distributions, with disc-bearing stars rotating on average slower than stars without discs. A mass-rotation dependence was also verified, but as in NGC 6530, very low mass stars ($M < 0.4M_\odot$) are rotating on average slower than higher mass stars ($0.4M_\odot < M < 1.4M_\odot$). We observed an excess of slow rotators among the lower mass population. The disc and mass-rotation connection was also analysed by taking into account the incident UV radiation arising from O stars in the association. Results compatible with the disc-locking scenario were verified for stars with low UV incidence, but no statistical significant relation between rotation and disc presence was verified for stars with high UV incidence, suggesting that massive stars can have an important role on regulating the nearby low mass stars rotation.

https://drive.google.com/file/d/0ByEXKJP1NU1lZ1AyRk1SUZnWFk/view?usp=sharing
Postdoctoral Position on Protoplanetary Disk Structure & Planet Formation at the University of Exeter

The Astrophysics Group of the University of Exeter wishes to recruit a highly qualified postdoctoral researcher to work on observational studies related to protoplanetary disk structure and planet formation.

The post is available for 3 years beginning November 2017 (later start dates in 2018 will also be considered). The fellow will join an ambitious team of postdocs and PhD students and work with Prof. Stefan Kraus on studying time-variable, planet-induced structures in the inner-most AU of protoplanetary disks. We have access to data from ALMA, the VLT Interferometer, and the CHARA array and lead the CHARA/MIRCX instrumentation project that will enable efficient milliarcsecond-resolution imaging of young stellar objects. The fellow will be involved in the commissioning and scientific exploitation of this new instrument and work on interpreting the observations with the latest physical models. We are particularly interested in applicants with expertise in radiative transfer modelling of complex multi-wavelength data sets and/or in high-angular imaging techniques (e.g. ALMA, VLTI, adaptive optics). Prior experience with the technique of interferometry is not required, but would be an asset.

The position is funded by the European Research Council (ERC), with an annual salary in the range GBP 28,452 to GBP 33,943. Applicants must possess a PhD in astrophysics or a related discipline, or expect to have earned one before taking up the position.

Detailed enquiries regarding scientific aspects can be made to Prof. Stefan Kraus (email: skraus@astro.ex.ac.uk). Candidates can apply on the Exeter online application system (https://goo.gl/n2AVr6). Please include a CV, publication list, a brief statement of research interests, and contact details for three referees.

AAS job register advert: https://jobregister.aas.org/ad/f1aa726e

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If you move or your e-mail address changes, please send the editor your new address. If the Newsletter bounces back from an address for three consecutive months, the address is deleted from the mailing list.
Meetings

Cosmic Cycle of Dust and Gas in the Galaxy: from Old to Young Stars
Quy Nhon, Vietnam from July 9th to 13th, 2018

The conference will take place at ICISE (http://www.icisequynhon.com/icise-about-us/).
The conference belongs to a cycle of conferences "Rencontres du Vietnam" about matter and dynamics of Star Forming Regions in our Galaxy. The "Rencontres du Vietnam" on the evolution of gas and dust content from evolved to young stars would like to bring together astronomers working on the circumstellar environment of evolved stars, astronomers working on star (and planet) forming regions and planetologists working on the origin of the solar system. A common conference bringing together these communities should provide a better understanding of the cycle of gas and dust from old stars to young ones, in particular, to our young Sun and its planetary system. The conference 'Blowing In the Wind' in 2016 has addressed the dynamical aspects. The 2017 conference about 'Star Formation in Different environments' focuses on how stars form. This conference is dedicated to the gas and dust physico-chemistry and evolution. We will review the molecular and dust contents of envelopes and shells around SuperNovae, AGB and planetary nebulae as those of diffuse, cold and giant molecular clouds. Special sessions will be also dedicated to the origin of material building our own Solar System (meteorite studies, Rosetta results). High-resolution spectroscopy provides unique information on the chemical compositions, the physical conditions, and the dynamics, in the different media from old star environments to protoplanetary disks. Thanks to its sensitivity and resolving power, ALMA is now allowing us to follow the evolution of matter along the cosmic cycle in our Galaxy and therefore such a conference is very timely. The conference will consist of plenary sessions with reviews, invited talks, oral and poster presentations (solicited or selected from abstract submissions). Special emphasis is placed on active participation of young researchers and post-docs. Since the audience of the conference will be very broad, a large fraction of time will be dedicated to review talks. The best poster will be awarded a prize.

The conference website is available at: https://cosmiccycle2018.sciencesconf.org/

First announcement:
Cool Stars 20: July 29 to Aug 3, 2018 in Boston / Cambridge, USA

The Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun ("Cool Stars") has been running for 37 years. The first workshop was held in Cambridge, Massachusetts in 1980. Since then, Cool Stars has been held largely biennially, alternating between North America and Europe, where approximately 400 international experts in Low-Mass Stars, Solar Physics, and Exoplanets meet to exchange ideas in a cross-disciplinary and friendly environment.

Four institutions in the Boston area (Boston University, Harvard-Smithsonian Center for Astrophysics (Harvard College Observatory / Smithsonian Astrophysical Observatory), MIT, and University of Massachusetts Lowell) jointly organize Cool Stars 20 which will be held at Boston University in Boston/Cambridge, MA from July 29 to August 03, 2018.

We will accept proposals for splinter sessions and abstracts for talks and posters in the fall of this year. Registration will open early in 2018. Until then, you can register on our website for further announcements.

More details can be found on the website http://www.coolstars20.com which is updated frequently.
Summary of Upcoming Meetings

Ages²: Taking stellar ages to the next power
18 - 22 September 2017, Elba, Italy
http://www.stsci.edu/institute/conference/ages2017

Planet Formation and Evolution 2017
25 - 27 September 2017, Jena, Germany
http://www.astro.uni-jena.de/~pfe2017

The Initial Mass Function: From Top to Bottom
10 November 2017, London, UK
https://rasimf2017.wordpress.com

Exoplanets and Planet Formation
11 - 15 December 2017, Shang Hai, China
https://indico.leeinst.sjtu.edu.cn/event/25/

Magnetic Fields or Turbulence: Which is the critical factor for the formation of stars and planetary disks?
6 - 9 February 2018, Hsinchu, Taiwan

EPoS 2018 The Early Phase of Star Formation - Archetypes
13 - 18 May 2018, Ringberg Castle, Tegernsee, Germany

The Olympian Symposium 2018: Gas and stars from milli- to mega- parsecs
28 May - 1 June 2018, Mt. Olympus, Greece
http://www.olympiansymposium.org

Cool Stars 20: Cambridge Workshop on Cool Stars, Stellar Systems and the Sun
29 July - 3 August 2018, Cambridge/Boston, USA
http://www.coolstars20.com