THE STAR FORMATION NEWSLETTER

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The Star Formation Newsletter

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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List of Contents

Cover Picture

The image shows the HII region and star forming region IC 417 (Sh2-234) which is part of the Aur OB2 association. The gas is excited by young massive stars in the partly embedded cluster Stock 8, located at a distance of approximately 2 kpc. The image combines exposures of Hα and [OIII]. North is up and east is left.

Image courtesy Sara Wager (http://www.swagastro.com).

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Perspective

The Myth of Fragmentation

by Steven W. Stahler

1 An Attractive Idea

All students and researchers in star formation have encountered the concept of fragmentation, the breakup of relatively large, self-gravitating entities into smaller ones. The idea figures prominently in studies ranging from molecular cloud dynamics to the evolution of circumstellar disks. Fragmentation, in one of its variants, often forms the intellectual backbone of these investigations. This is an unfortunate situation that has impeded progress in our field for many years. In my opinion, there is no evidence, either from observation or theory, that fragmentation actually occurs, at least within the realm of star formation. It is time that we move beyond this outdated notion to a picture that more plausibly describes astrophysical reality. I cannot yet discern every feature of the new landscape. Instead I will try to sketch its topography, indicating directions for future research that I hope will prove useful.

Fragmentation is an old idea, and an understandably attractive one. As we survey the interstellar medium, looking for the precursors to stars, we find, in descending order of size: giant molecular complexes, clumps within these complexes, relatively tiny dense cores embedded within clumps, and finally stars themselves. Surely, these objects must be related. A grand idea, easy to grasp and sweeping in scope, is that this observed morphological sequence of gaseous bodies also represents a temporal sequence. Giant complexes break into clumps, which in turn break into dense cores, and so on.

This is the "top-down" view of star formation, and it still dominates present-day thinking. Whatever, its basic, intuitive appeal, the idea suffers from an equally basic problem. On its own, an object does not spontaneously break apart into denser fragments. At each stage in the putative hierarchical process, the parent body can only fragment if it is significantly out of force balance. Self-gravity, which causes fragments to congeal, must be stronger than any combination of forces supporting the body.

How does this force imbalance arise? The only possibility that has ever been offered is that the object is assembled quickly, before it has time to contract. Once in place, the overly massive body collapses inward and breaks apart. The earlier process of rapid gas accumulation is rarely described explicitly (for one such attempt, see Ballesteros-Paredes et al 1999), much less justified empirically. But in the absence of other explanations, such early condensation must be present implicitly in *all* simulations that start with full collapse.

Now gravitational collapse certainly occurs when a dense core spawns an individual protostar. However, the dense core does not begin out of force balance, but close to it, and the result is a star, not a collection of fragments. More generally, it is implausible that rapid coalescence followed by fragmenting collapse plays a dominant role in all the multi-scale phenomena associated with star formation.

I have just sketched out both a big idea, and what I view as the major problem with that idea. To clarify things further, let me now consider two specific examples, areas where fragmentation is currently thought to occur, and where it has led to serious conceptual difficulty. The parent objects of interest will be giant molecular clouds and the dense cores that form binary stars. In both cases, I will argue that the object does not dynamically fragment.

2 Molecular Clouds

For many years, theorists have been simulating the collapse and fragmentation of molecular clouds, using ever faster computers and incorporating a growing list of physical effects. These calculations are the most ambitious in the field. Not only do researchers hope to explain the structure of clouds themselves, but even the basic properties of the stars they create, including the initial mass function.

All simulations are done in a computational box of fixed size. Thus, they represent a *portion* of a much larger cloud. In addition, researchers endow the gas with some degree of random, turbulent motion from the start. This latter ingredient of the simulations reflects the observed fact that all molecular clouds larger than dense cores have molecular emission lines of superthermal width. We have known for decades that the corresponding speeds are virial, based on the clouds masses and sizes (Larson 1981). Moreover, the

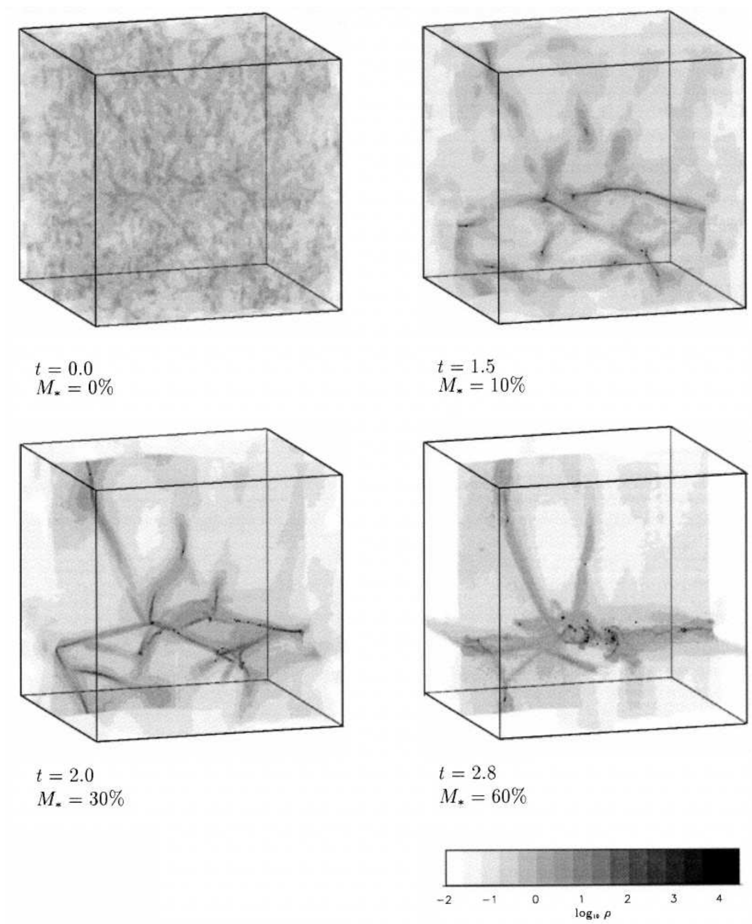

Figure 1: Evolution of the density distribution in a computational box representing a portion of a molecular cloud. The gas initially has no internal velocity, but a Gaussian pattern of density perturbations. Soon, the velocity everywhere grows and clumps arise. From Klessen & Burkert (2000).

speed in one patch of a cloud is correlated with that in a neighboring patch (Heyer & Brunt 2004).

These are both important, solidly established facts. Beyond them, we still have little direct evidence either for the physical origin of the turbulence (see Dobbs et al 2014 for a discussion) or for the actual spatial pattern of this motion within any cloud. The numerical techniques employed to simulate turbulence are artificial means for obtaining the requisite velocities, methods that happen to be the most easy to implement on the computer.

What happens in these simulations can be broadly summarized. At $t = 0$, the gas begins to collapse inward and fragment. The fragments are much smaller than the full computational volume. They also have a far higher density than the original gas. Density is enhanced when oppositely directed turbulent streams collide and shock. If the post-shock gas is also cold enough, it further collapses under the influence of self-gravity. Eventually, isolated regions are created which are so compact that they are counted as stars, although the computed density at this point is still far less than that of an actual star (see Fig. 1).

The parent clouds in these simulations are either initially far out of force balance, or else quickly become so. In some experiments, the total kinetic energy in turbulent motion, plus the relatively tiny energy in microscopic thermal motion, is far less than the bulk gravitational energy from the start (Klessen & Burkert 2000). In others, the kinetic and potential energies are comparable at first (Bate et al 2003). It makes little practical difference, since the kinetic energy is lost in shocks within a single crossing time. Even if the turbulence is continually driven throughout the collapse, the outcome is essentially the same (Klessen 2001). Most of the kinetic energy vanishes so quickly that there is soon relatively little diffuse gas subjected to the driving. The bulk of the gas goes into headlong collapse and fragmentation.

Researchers are busy adding more features to these simulations. For example, it is technically challenging to treat in detail the trapping of any magnetic field threading the parent cloud. One might also desire a more refined treatment of the effects of winds being driven by the stars created. Over and above these details, one should ask if this general picture, obtained consistently by many calculations, is a realistic description of how molecular clouds actually evolve.

I don't believe it is. Since each simulation tracks only a small portion of the entire cloud, it is legitimate to ask what might be happening in other portions. Yet another standard technique in the simulations is to employ periodic boundary conditions at all faces of the computational box. In effect, one is assuming that all neighboring portions of the parent cloud evolve identically to the one being examined, which is collapsing on the fastest possible (dynamical) time scale. As indicated earlier, there is no firm understanding, backed by observations, of how the extended cloud arrived at such a state. It is equally difficult to entertain the alternative view, that one portion evolves quickly, while its surrounding environment does not.

A key hypothesis here is that clumps within clouds are generated through shocks. In principle, one could test this idea by searching for the emission lines from relatively low-velocity shocks (e.g., Kaufman & Neufeld 1996). I hope such a search will be done, but I would not bet on its success. All self-gravitating clouds are observed to be clumpy, and it is unlikely that we happen to be observing them just after they formed via rapid coalescence. More probably, they were born with a clumpy morphology. Why this should be so is an interesting question, and one that could be answered by theory.

As for the clouds' turbulence, Larson's original observation of virial velocities continues to indicate that self-gravity is the driving mechanism. But what, more precisely, is the causal link between gravity and turbulence? Suppose the clumps are relatively stable and long-lived. Then their slow contraction could release energy to power turbulence. If this picture is valid, then simulations modeling small portions of a cloud cannot capture it. And if the clump is not just a transient entity, then the current numerical prescription for simulating turbulence through randomly stirring gas creates too much dissipation. Somehow, the clump undergoes a more organized kind of internal churning, in which shocks are the exception rather than the rule. Even the most simplified account of such dynamics would represent a major step forward.

3 Binary Stars

How binary stars form is a venerable question that first exercised physicists and mathematicians over a century ago, and is still a mystery today. The early idea that a star rotating fast enough would split into two was refuted in the 1980s (Durisen et al 1986). Simulations demonstrated that a rapidly rotating body sheds angular momentum in a pair of trailing spiraling arms. Another influential idea was that binaries form through gravitational capture. We now understand that capture can occur, but only in very dense stellar environments, where energy is either transferred to a nearby third body (e.g., Terlevich 1987), or else dissipated via tidal interaction of the two stars in question, as originally proposed by Fabian et al (1975) for globular clusters. How binaries arise in the sparser regions of low-mass star formation remains the outstanding issue.

The two leading models at present both invoke fragmentation of a dense core. Like all fragmentation schemes, these require the parent body to be out of force balance. Equivalently, the body's actual mass must exceed its Jeans mass, where the latter is calculated for the density and the effective temperature associated with the combined forces of mechanical support. A convenient and sensible rule of thumb, corroborated by decades of simulations, is that each body produces roughly N_J fragments, where N_J is the number of Jeans masses at the start of collapse. For a dense core to produce a binary, and no other stars, via this route, we need $N_J = 2$. That is, the parent cloud has too much self-gravity, but not to a large degree.

In the *turbulent fragmentation* picture, the dense core is initially spherical and non-rotating, but contains a certain amount of turbulence. Usually, the total energy in turbulence is assumed to be relatively small, consistent with observations of dense cores (Goodman et al 1998). This internal, random motion is generated numerically in just the same way as in the simulated collapse of much larger molecular clouds.

Goodwin et al (2004) endowed their spherical core with a Plummer density profile, an analytic prescription that describes fairly well the observations of more concentrated (protostellar) starless cores. Since the Plummer sphere is not a solution for the equations of hydrostatic equilibrium, the cloud immediately collapses to a flattened, more compact structure. This entity draws in turbulent eddies and thereby acquires a net rotation. Eventually, it grows spiral arms that may or may not fragment, depending on the detailed properties of the imposed velocity field. A higher degree of initial turbulence generally yields a larger number of fragments (Fig. 2). No one has suggested how the slightly overmassive cloud might arise in the first place.

Another approach has been to posit non-turbulent, spherical clouds, as long as they start with some bulk rotation. These models exemplify *rotational fragmentation.* Machida et al (2008) employ such an initial state, giving it the Bonnor-Ebert density profile. This is an exact solution for a (non-rotating) isothermal equilibrium. However, since fragmentation requires the configuration to collapse fully from the start, the authors increased the initial density everywhere by a certain amount, typically 10 percent. They further added a bar-like perturbation of the density in order to promote breakup. The cloud again collapsed promptly to a flattened structure near the center of the computational domain, and fragmentation came from the breakup of either a ring- or bar-like structure. Arreaga-Garcia et al (2010) have presented a similar model, including the bar-like perturbation, but with an initial Plummer density profile.

These examples suffice to show that there is no unique way to implement the requirement that $N_J = 2$. A range of initial cloud states will collapse and break up into two or more stable fragments. The exact route for this breakup differs from one model to the next. Of course, we are still a long way from being able to account for the rich observations of young binary stars (Reipurth et al 2014). To tie theory and observation together, a more fruitful approach might be to start from the empirical properties of dense cores that have produced embedded pairs of stars. Is it possible to explain these observations without invoking the artificial condition that the cloud be in full collapse from the start?

The observed shapes of dense cores are two-dimensional projections, and it requires statistical analysis to infer their underlying, three-dimensional structure. Such analysis has long indicated that the cores are elongated, prolate objects (Ryden 1996). For a time, this inference met with some resistance. The issue has now been settled with the finding that cores often reside within larger filaments, in which case their long axes align with that of these parent structures (e.g., Tafalla & Hacar 2015). It is no longer tenable that the cores are flattened structures viewed nearly edge on; they are indeed prolate, like the filaments themselves. Note finally that when a dense core contains a primitive binary, consisting of two Class 0 sources, the stars similarly align with the core's central axis (see Fig. 3). These embedded stars, not yet gravitationally bound to each other, must have formed along that axis.

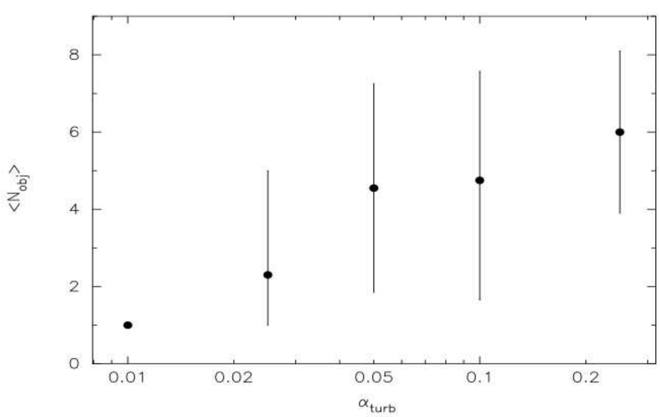

Figure 2: The number of fragments produced by a collapsing cloud, as a function of the degree of initially imposed turbulence. The amount of turbulence is expressed as $\alpha_{\rm turb}$, the ratio of the initial turbulent kinetic energy to the gravitational potential energy of the cloud. From Goodwin et al (2004).

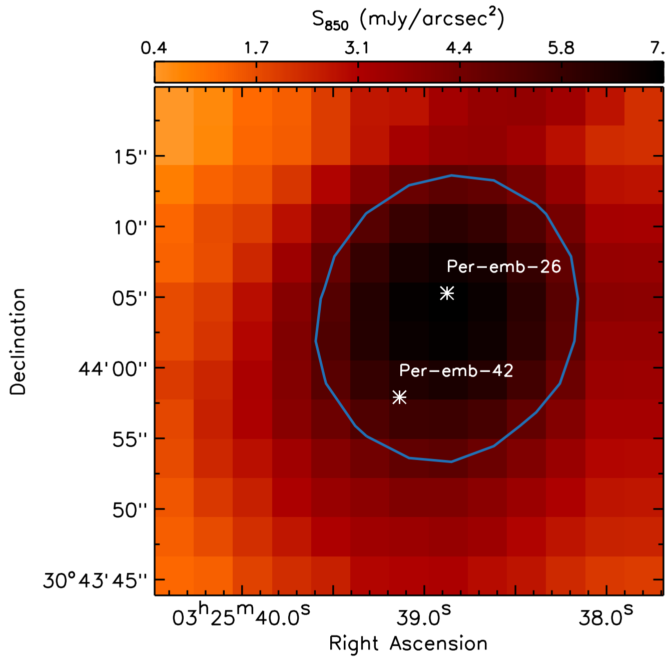

Figure 3: The dense core L1448-C in Perseus, along with its embedded binary (Sadavoy & Stahler, in preparation). Shown is a SCUBA-2 850 μm map from the initial release of the JCMT Gould Belt Survey (Chun-Yuan Chen et al. 2016). The binary is from the VANDAM radio survey of Tobin et al (2016).

Returning to filaments, it is found that some have relatively smooth interior densities; they contain no cores. Both the lengths and diameters of these barren filamants are similar to those with cores; they simply have less internal mass (Arzoumanian et al 2014). It thus appears that the origin of binaries is closely linked to that of dense cores themselves. Cores seem to accumulate inside each filament as it accretes gas from the outside. As the elongated core grows in mass, it often develops a density concentration at both ends. These concentrations become more pronounced until they eventually collapse to form stellar binaries. At first, the stars are bound only to the host core, but they gradually drift together as their winds dissipate the parent cloud. In this "bottom-up" picture, the collapse of the cloud is the end result of a quasi-static evolutionary process, and is not present at the start.

4 Summary

The idea that the precursors to stars fragment hierarchically traces its origin to the very early work of Hoyle (1953), written in an era long before detailed theoretical calculations in star formation. The situation today is entirely different. The vast majority of theoretical studies consist of computationally intensive simulations that supply a flood of numerical results. Moreover, since fragmentation requires an actively collapsing body, even slight differences of initial conditions often lead to qualitatively different outcomes. Supplied with robust, often publicly accessible, computer codes, researchers have delivered a steady stream of fragmentation studies for two decades.

It may be, however, that we are being dazzled, if not blinded, by the very power of our technical tools. We believe in just those processes which computers track most easily. These are fully dynamical situations, in which fluid elements cross a significant portion of the numerical grid in a practical, computable time. In the evolutionary processes we have considered, this restricted perspective translates into the stipulation that the parent body be in full collapse from the start. The difficulty is in specifying plausible conditions leading to this circumstance. Mass must be accrued quickly. If it gathers together slowly, the parent body will eventually collapse, but without fragmenting. This slow, bottom-up route is still largely unexplored.

Fragmentation is a big idea that is supposed to apply to a broad range of size scales and physical conditions. It will not be replaced by another overarching scheme, but by a variety of models that apply to specific problems. Full collapse and fragmentation can often yield interesting structure, but we should not be content with such an account. The slow route is ultimately more promising.

A final case in point is the cloud filaments that often contain dense cores. It is not difficult to obtain filaments through a simulation of cloud collapse (e.g., Peters et al 2012). Moving beyond such calculations means finding circumstances under which filaments appear, gather mass, and condense within a slowly evolving cloud interior. Any such investigation, if it is to be more than schematic, will ultimately be numerical. But the qualitative result to be sought is a gentler, less dynamic evolution. A new generation of models is needed, and it will be exciting to see them arriving on the scene.

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Abstracts of recently accepted papers

The Spiral Wave Instability Induced by a Giant Planet: I. Particle Stirring in the Inner Regions of Protoplanetary Disks

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We have recently shown that spiral density waves propagating in accretion disks can undergo a parametric instability by resonantly coupling with and transferring energy into pairs of inertial waves (or inertial-gravity waves when buoyancy is important). In this paper, we perform inviscid three-dimensional global hydrodynamic simulations to examine the growth and consequence of this instability operating on the spiral waves driven by a Jupiter-mass planet in a protoplanetary disk. We find that the spiral waves are destabilized via the spiral wave instability (SWI), generating hydrodynamic turbulence and sustained radially-alternating vertical flows that appear to be associated with long wavelength inertial modes. In the interval $0.3\ R_p \leq R \leq 0.7\ R_p$, where R_p denotes the semi-major axis of the planetary orbit (assumed to be 5 au), the estimated vertical diffusion rate associated with the turbulence is characterized by $\alpha_{\rm diff} \sim (0.2 - 1.2) \times 10^{-2}$. For the disk model considered here, the diffusion rate is such that particles with sizes up to several centimeters are vertically mixed within the first pressure scale height. This suggests that the instability of spiral waves launched by a giant planet can significantly disperse solid particles and trace chemical species from the midplane. In planet formation models where the continuous local production of chondrules/pebbles occurs over Myr time scales to provide a feedstock for pebble accretion onto these bodies, this stirring of solid particles may add a time constraint: planetary embryos and large asteroids have to form before a gas giant forms in the outer disk, otherwise the SWI will significantly decrease the chondrule/pebble accretion efficiency.

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https://arxiv.org/pdf/1610.08502

In Situ Formation and Dynamical Evolution of Hot Jupiter Systems

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Hot Jupiters, giant extrasolar planets with orbital periods shorter than ∼10 days, have long been thought to form at large radial distances, only to subsequently experience long-range inward migration. Here, we offer the contrasting view that a substantial fraction of the hot Jupiter population formed in situ via the core-accretion process. We show that under conditions appropriate to the inner regions of protoplanetary disks, rapid gas accretion can be initiated by super-Earth-type planets, comprising 10-20 Earth masses of refractory material. An in situ formation scenario leads to testable consequences, including the expectation that hot Jupiters should frequently be accompanied by additional low-mass planets with periods shorter than ∼100 days. Our calculations further demonstrate that dynamical interactions during the early stages of planetary systems lifetimes should increase the inclinations of such companions, rendering transits rare. High-precision radial velocity monitoring provides the best prospect for their detection.

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http://arxiv.org/pdf/1511.09472.pdf

Physical parameters of late M-type members of Chamaeleon I and TW Hydrae Association: Dust settling, age dispersion and activity

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Although mid-to-late type M dwarfs are the most common stars in our stellar neighborhood, our knowledge of these objects is still limited. Open questions include the evolution of their angular momentum, internal structures, dust settling in their atmospheres, age dispersion within populations. In addition, at young ages, late-type Ms have masses below the hydrogen burning limit and therefore are key objects in the debate on the brown dwarf mechanism of formation. In this work we determine and study in detail the physical parameters of two samples of young, late M-type sources belonging to either the Chamaeleon I Dark Cloud or the TW Hydrae Association and compare them with the results obtained in the literature for other young clusters and also for older, field, dwarfs. We used multi-wavelength photometry to construct and analyze SEDs to determine general properties of the photosphere and disk presence. We also used low resolution optical and near-infrared spectroscopy to study activity, accretion, gravity and effective temperature sensitive indicators. We propose a VO-based spectral index that is both temperature and age sensitive. We derived physical parameters using independent techniques confirming the already common feature/problem of the age/luminosity spread. In particular, we highlight two brown dwarfs showing very similar temperatures but clearly different surface gravity (explained invoking extreme early accretion). We also show how, despite large improvement in the dust treatment in theoretical models, there is still room for further progress in the simultaneous reproduction of the optical and near-infrared features of these cold young objects.

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http://arxiv.org/pdf/1610.06951v1

Shadows and spirals in the protoplanetary disk HD 100453

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Context. Understanding the diversity of planets requires to study the morphology and the physical conditions in the protoplanetary disks in which they form.
Aims. We aim to study the structure of the ∼10 Myr old protoplanetary disk HD 100453, to detect features that can trace disk evolution and to understand the mechanisms that drive these features.
Methods. We observed HD 100453 in polarized scattered light with SPHERE/VLT at optical (0.6 μm, 0.8 μm) and near-infrared (1.2 μm) wavelengths, reaching an angular resolution of ∼0.02", and an inner working angle of ∼0.09".
Results. We spatially resolve the disk around HD 100453, and detect polarized scattered light up to ∼0.42" (∼48 au). We detect a cavity, a rim with azimuthal brightness variations and inclined by ∼38° with respect to our line of sight, two shadows and two symmetric spiral arms. The spiral arms originate near the location of the shadows, close to the semi major axis. We detect a faint feature in the SW that can be interpreted as the scattering surface of the bottom side of the disk, if the disk is tidally truncated by the M-dwarf companion currently seen at a projected distance of ∼119 au. We construct a radiative transfer model that accounts for the main characteristics of the features with an inner and outer disk misaligned by ∼72°. The azimuthal brightness variations along the rim are well reproduced with the model scattering phase function. While spirals can be triggered by the tidal interaction with the companion, the close proximity of the spirals to the shadows suggests that the shadows could also play a role. The change in stellar illumination along the rim, induces an azimuthal variation of the scale height that can contribute to the brightness variations.
Conclusions. Dark regions in polarized images of transition disks are now detected in a handful of disks and often interpreted as shadows due to a misaligned inner disk. However, the origin of such a misalignment in HD 100453, and of the spirals, is still unclear, and might be due to a yet-undetected massive companion inside the cavity, and on an inclined orbit. Observations over a few years will allow to measure the spiral pattern speed, and if the shadows are fixed or moving, which may constrain their origin.

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Misaligned Disks in the Binary Protostar IRS 43

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Recent high angular resolution (∼0.″2) ALMA observations of the 1.1 mm continuum and of HCO^+ J=3–2 and HCN J=3–2 gas towards the binary protostar IRS 43 reveal multiple Keplerian disks which are significantly misaligned (>60°), both in inclination and position angle and also with respect to the binary orbital plane. Each stellar component has an associated circumstellar disk while the binary is surrounded by a circumbinary disk. Together with archival VLA measurements of the stellar positions over 25 years, and assuming a circular orbit, we use our continuum measurements to determine the binary separation, $a = 74 \pm 4$ AU, and its inclination, $i < 30°$. The misalignment in this system suggests that turbulence has likely played a major role in the formation of IRS 43.

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The influence of dust grain porosity on the analysis of debris disc observations

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Debris discs are often modelled assuming compact dust grains, but more and more evidence for the presence of porous grains is found. We aim at quantifying the systematic errors introduced when modelling debris discs composed of porous dust with a disc model assuming spherical, compact grains. We calculate the optical dust properties derived via the fast, but simple effective medium theory. The theoretical lower boundary of the size distribution - the so-called 'blowout size' - is compared in the cases of compact and porous grains. Finally, we simulate observations of hypothetical debris discs with different porosities and feed them into a fitting procedure using only compact grains. The deviations of the results for compact grains from the original model based on porous grains are analysed. We find that the blowout size increases with increasing grain porosity up to a factor of two. An analytical approximation function for the blowout size as a function of porosity and stellar luminosity is derived. The analysis of the geometrical disc set-up, when constrained by radial profiles, are barely affected by the porosity. However, the determined minimum grain size and the slope of the grain size distribution derived using compact grains are significantly overestimated. Thus, the unexpectedly high ratio of minimum grain size to blowout size found by previous studies using compact grains can be partially described by dust grain porosity, although the effect is not strong enough to completely explain the trend.

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Testing dust trapping in the circumbinary disk around GG Tau A

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The protoplanetary disk around the GG Tau A binary system is so far one of the most studied young circumbinary disk. Observations of the dust continuum emission at sub-mm/mm wavelengths detected a dust ring located between 200AU and 300AU from the center of mass of the system. If the disk and the binary orbit are coplanar, given the observed projected separation of the stars in the binary system, the classical theory of tidal interaction between a binary system and its circumbinary disk predicts a truncation radius which is significantly smaller than the measured inner radius of the mm-sized dust ring. We investigate the origin of this dust ring structure in the GG Tau A disk, test whether the interaction between the binary and the disk can produce a dust trap at the location of the observed ring, and discuss an alternative scenario which invokes a misalignment between the disk and the stellar orbital planes. We run a set of hydrodynamical simulations for an orbit consistent with the astrometric solutions for the GG Tau A stellar proper motions, and for different disk temperature and viscosities. We then apply a dust evolution model in post-processing in order to to retrieve the distribution of mm-sized grains. Comparing models and observations, we show that, if the binary orbit and the disk were coplanar,the tidal truncation of the circumbinary disk would occur at a radius that is too small compared to the inner edge inferred by the dust observations, and that the pressure bump and the dust ring in the models would be located at <150AU from the center of mass of the stellar system. This shows that the GG Tau A disk cannot be coplanar with the binary orbital plane. We also discuss the viability of the misaligned disk scenario, suggesting that in order for dust trapping to occur at the observed radius, the disk and orbital plane must be misaligned by an angle of about 25 degrees.

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The Coupled Physical Structure of Gas and Dust in the IM Lup Protoplanetary Disk

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The spatial distribution of gas and solids in protoplanetary disks determines the composition and formation efficiency of planetary systems. A number of disks show starkly different distributions for the gas and small grains compared to millimeter-centimeter sized dust. We present new Atacama Large Millimeter/Submillimeter Array (ALMA) observations of the dust continuum, CO, ^{13}CO, and $C^{18}O$ in the IM Lup protoplanetary disk, one of the first systems where this dust-gas dichotomy was clearly seen. The ^{12}CO is detected out to a radius of 970 AU, while the millimeter continuum emission is truncated at just 313 AU. Based upon this data, we have built a comprehensive physical and chemical model for the disk structure, which takes into account the complex, coupled nature of the gas and dust and the interplay between the local and external environment. We constrain the distributions of gas and dust, the gas temperatures, the CO abundances, the CO optical depths, and the incident external radiation field. We find that the reduction/removal of dust from the outer disk exposes this region to higher stellar and external radiation and decreases the rate of freeze-out, allowing CO to remain in the gas out to large radial distances. We estimate a gas-phase CO abundance of 5% of the ISM value and a low external radiation field ($G_0 \lesssim 4$). The latter is consistent with that expected from the local stellar population. We additionally find tentative evidence for ring-like continuum substructure, suggestions of isotope-selective photodissociation, and a diffuse gas halo.

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The Magnetic Field of L1544: I. Near-Infrared Polarimetry and the Non-Uniform Envelope

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The magnetic field (B-field) of the starless dark cloud L1544 has been studied using near-infrared (NIR) background starlight polarimetry (BSP) and archival data in order to characterize the properties of the plane-of-sky B-field. NIR linear polarization measurements of over 1,700 stars were obtained in the H-band and 201 of these were also measured in the K-band. The NIR BSP properties are correlated with reddening, as traced using the RJCE ($H - M$) method, and with thermal dust emission from the L1544 cloud and envelope seen in Herschel maps. The NIR polarization position angles change at the location of the cloud and exhibit their lowest dispersion of position angles there, offering strong evidence that NIR polarization traces the plane-of-sky B-field of L1544. In this paper, the uniformity of the plane-of-sky B-field in the envelope region of L1544 is quantitatively assessed. This allowed evaluating the approach of assuming uniform field geometry when measuring relative mass-to-flux ratios in the cloud envelope and core based on averaging of the envelope radio Zeeman observations, as in Crutcher et al. (2009). In L1544, the NIR BSP shows the envelope B-field to be significantly non-uniform and likely not suitable for averaging Zeeman properties without treating intrinsic variations. Deeper analyses of the NIR BSP and related data sets, including estimates of the B-field strength and testing how it varies with position and gas density, are the subjects of later papers in this series.

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Impacts of fragmented accretion streams onto Classical T Tauri Stars: UV and X-ray emission lines

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Context. The accretion process in Classical T Tauri Stars (CTTSs) can be studied through the analysis of some UV and X-ray emission lines which trace hot gas flows and act as diagnostics of the post-shock downfalling plasma. In the UV band, where higher spectral resolution is available, these lines are characterized by rather complex profiles whose origin is still not clear.
Aims. We investigate the origin of UV and X-ray emission at impact regions of density structured (fragmented) accretion streams.We study if and how the stream fragmentation and the resulting structure of the post-shock region determine the observed profiles of UV and X-ray emission lines.
Methods. We model the impact of an accretion stream consisting of a series of dense blobs onto the chromosphere of a CTTS through 2D MHD simulations. We explore different levels of stream fragmentation and accretion rates. From the model results, we synthesize C IV (1550 Å) and OVIII (18.97 Å) line profiles.
Results. The impacts of accreting blobs onto the stellar chromosphere produce reverse shocks propagating through the blobs and shocked upflows. These upflows, in turn, hit and shock the subsequent downfalling fragments. As a result, several plasma components differing for the downfalling velocity, density, and temperature are present altogether. The profiles of C IV doublet are characterized by two main components: one narrow and redshifted to speed ≈ 50 km s^{-1} and the other broader and consisting of subcomponents with redshift to speed in the range $200 - 400$ km s^{-1}. The profiles of OVIII lines appear more symmetric than C IV and are redshifted to speed ≈ 150 km s^{-1}.
Conclusions. Our model predicts profiles of C IV line remarkably similar to those observed and explains their origin in a natural way as due to stream fragmentation.

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A population of eruptive variable protostars in VVV

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We present the discovery of 816 high amplitude infrared variable stars ($\Delta K_s > 1$ mag) in 119 deg^2 of the Galactic midplane covered by the Vista Variables in the Via Lactea (VVV) survey. Almost all are new discoveries and about 50% are YSOs. This provides further evidence that YSOs are the commonest high amplitude infrared variable stars in the Galactic plane. In the 2010-2014 time series of likely YSOs we find that the amplitude of variability increases towards younger evolutionary classes (class I and flat-spectrum sources) except on short timescales (<25 days) where this trend is reversed. Dividing the likely YSOs by light curve morphology, we find 106 with eruptive light curves, 45 dippers, 39 faders, 24 eclipsing binaries, 65 long-term periodic variables (P>100 days) and 162 short-term variables. Eruptive YSOs and faders tend to have the highest amplitudes and eruptive systems have the reddest SEDs. Follow up spectroscopy in a companion paper verifies high accretion rates in the eruptive systems. Variable extinction is disfavoured by the 2 epochs of colour data. These discoveries increase the number of eruptive variable YSOs by a factor of at least 5, most being at earlier stages of evolution than the known FUor and EXor types. We find that eruptive variability is at least an order of magnitude more common in class I YSOs than class II YSOs. Typical outburst durations are 1 to 4 years, between those of EXors and FUors. They occur in 3 to 6% of class I YSOs over a 4 year time span.

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Infrared spectroscopy of eruptive variable protostars from VVV

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In a companion work (Paper I) we detected a large population of highly variable Young Stellar Objects (YSOs) in the Vista Variables in the Via Lactea (VVV) survey, typically with class I or flat spectrum spectral energy distributions and diverse light curve types. Here we present infrared spectra (0.9–2.5 μm) of 37 of these variables, many of them observed in a bright state. The spectra confirm that 15/18 sources with eruptive light curves have signatures of a high accretion rate, either showing EXor-like emission features (Δv=2 CO, Brγ) and/or FUor-like features (Δv=2 CO and H_2O strongly in absorption). Similar features were seen in some long term periodic YSOs and faders but not in dippers or short-term variables. The sample includes some dusty Mira variables (typically distinguished by smooth Mira-like light curves), 2 cataclysmic variables and a carbon star. In total we have added 19 new objects to the broad class of eruptive variable YSOs with episodic accretion. Eruptive variable YSOs in our sample that were observed at bright states show higher accretion luminosities than the rest of the sample. Most of the eruptive variables differ from the established FUor and EXor subclasses, showing intermediate outburst durations and a mixture of their spectroscopic characteristics. This is in line with a small number of other recent discoveries. Since these previously atypical objects are now the majority amongst embedded members of the class, we propose a new classification for them as MNors. This term (pronounced emnor) follows V1647 Ori, the illuminating star of McNeil's Nebula.

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Runaway gas accretion and gap opening versus type I migration

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Growing planets interact with their natal protoplanetary disc, which exerts a torque onto them allowing them to migrate in the disc. Small mass planets do not affect the gas profile and migrate in the fast type I migration. Although type I migration can be directed outwards for planets smaller than 20–30 $M_\oplus$, planets above this mass should be lost into the central star long before the disc disperses. Massive planets open a gap and subsequently migrate in the slower, type II migration, which could save them from migrating all the way to the star. Hence, growing giant planets can be saved if and only if they can reach the gap opening mass, because this extends their migration time-scale, allowing them to eventually survive at large orbits until the disc itself disperses.
However, most of the previous studies only measured the torques on planets with fixed masses and orbits to determine the migration rate. Additionally, the transition between type I and type II migration itself is not well studied. Here we use isothermal 2D disc simulations with FARGO-2D1D to study the migration behaviour of gas accreting protoplanets in discs. We find that migrating giant planets always open gaps in the disc. We further show analytically and numerically that planets growing in the runaway gas accretion regime will reach gap opening masses before migrating all the way to the central star if the disc is not extremely viscous and/or thick. An accretion rate limited to the radial gas flow in the disc, in contrast, is not fast enough. When gas accretion by the planet is taken into account, the gap opening process is accelerated because the planet accretes material originating from its horseshoe region. This allows an accreting planet to transition to type II migration before being lost even if gas fails to be provided for a rapid enough growth and the gap opening mass is not reached.

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Multi-wavelength study of star-formation in the S237 H II region

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We present a detailed multi-wavelength study of observations from X-ray, near-infrared to centimeter wavelengths to probe the star formation processes in the S237 region. Multi-wavelength images trace an almost sphere-like shell morphology of the region, which is filled with the 0.5–2 keV X-ray emission. The region contains two distinct environments - a bell-shaped cavity-like structure containing the peak of 1.4 GHz emission at center, and elongated filamentary features without any radio detection at edges of the sphere-like shell - where *Herschel* clumps are detected. Using the 1.4 GHz continuum and ^{12}CO line data, the S237 region is found to be excited by a radio spectral type of B0.5V star and is associated with an expanding HII region. The photoionized gas appears to be responsible for the origin of the bell-shaped structure. The majority of molecular gas is distributed toward a massive *Herschel* clump (M_{clump} ∼260 $M_\odot$), which contains the filamentary features and has a noticeable velocity gradient. The photometric analysis traces the clusters of young stellar objects (YSOs) mainly toward the bell-shaped structure and the filamentary features. Considering the lower dynamical age of the H II region (i.e. 0.2-0.8 Myr), these clusters are unlikely to be formed by the expansion of the H II region. Our results also show the existence of a cluster of YSOs and a massive clump at the intersection of filamentary features, indicating that the collisions of these features may have triggered cluster formation, similar to those found in Serpens South region.

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The physical environment around IRAS 17599-2148: infrared dark cloud and bipolar nebula

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We present a multi-scale and multi-wavelength study to investigate the star formation process around IRAS 17599−2148 that is part of an elongated filamentary structure (EFS) (extension ∼21 pc) seen in the *Herschel* maps. Using the *Herschel* data analysis, at least six massive clumps (M_{clump} ∼777 – 7024 $M_\odot$) are found in the EFS with a range of temperature and column density of ∼16–39 K and ∼0.6–11 × 10^{22} cm^{-2} (A_V ∼7–117 mag), respectively. The EFS hosts cold gas regions (i.e. infrared dark cloud) without any radio detection and a bipolar nebula (BN) linked with the H II region IRAS 17599−2148, tracing two distinct environments inferred through the temperature distribution and ionized emission. Based on virial analysis and higher values of self-gravitating pressure, the clumps are found unstable against gravitational collapse. We find 474 young stellar objects (YSOs) in the selected region and ∼72% of these YSOs are found in the clusters distributed mainly toward the clumps in the EFS. These YSOs might have spontaneously formed due to processes not related to the expanding H II region. At the edges of BN, four additional clumps are also associated with YSOs clusters, which appear to be influenced by the expanding H II region. The most massive clump in the EFS contains two compact radio sources traced in the GMRT 1.28 GHz map and a massive protostar candidate, IRS 1 prior to an ultracompact H II phase. Using the VLT/NACO near-infrared images, IRS 1 is resolved with a jet-like feature within a 4200 AU scale.

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New Parallaxes and a Convergence Analysis for the TW Hya Association

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The TW Hya Association (TWA) is a nearby stellar association with an age of ∼5–10 Myr. This is an important age for studying the late stages of star and planet formation. We measure the parallaxes of 14 candidate members of TWA. That brings to 38 the total number of individual stars with fully measured kinematics, i.e. proper motion, radial velocity, and parallax, to describe their motions through the Galaxy. We analyze these kinematics to search for convergence to a smaller volume in the past, but we find the association is never much more compact than it is at present. We show that it is difficult to measure traceback ages for associations such as TWA that have expected velocity dispersions of 1–2 km s^{-1} with typical measurement uncertainties. We also use our stellar distances and pre-main-sequence evolutionary tracks to find the average age of the association of 7.9±1.0 Myr. Additionally, our parallax measurement of TWA 32 indicates it should be considered a bona fide member of TWA. Two new candidate members have high membership probabilities, and we assign them TWA numbers: TWA 45 for 2MASS J11592786−4510192 and TWA 46 for 2MASS J12354615−4115531.

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The violent environment of the inner disk of RW Aur A probed by the 2010 and 2015 dimming events

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RW Aur is a young binary system showing strong signatures of a recent tidal encounter between the circumprimary disk and the secondary star. The primary star has recently undergone two major dimming events (Δmag ≈ 2 in V-band), whose origin is still under debate. To shed light on the mechanism leading to the dimming events, we study the extinction properties, accretion variability, and gas kinematics using absorption lines from the material obscuring star RW Aur A. We compare our moderate resolution X-Shooter spectra of the dim state of RW Aur A with other spectral observations. In particular, we analyse archival high resolution UVES spectra obtained during the bright state of the system, in order to track the evolution of the spectral properties across the second dimming event. Since the X-Shooter spectrum is flux-calibrated, we provide new synthetic photometry of RW Aur A during the dim state. The spectrum obtained during the dim state shows narrow absorption lines in the Na and K optical doublets, where the former is saturated. With a velocity of -60 km/s these lines indicate that during the dim state the disk wind is either enhanced, or significantly displaced into the line of sight. The photometric evolution across the dimming event shows a gray extinction, and is correlated with a significant reduction of the EW of all photospheric lines. Emission lines tracing accretion do not vary significantly across the dimming. Comparing our observations with complementary results from the last years, we conclude that the dimming event is related to a major perturbation on the inner disk. We suggest that the inner disk is occulting (most of) the star, and thus its photosphere, but is not occulting the accretion regions within a few stellar radii. Since observations of the outer disk indicate that the disk is modestly inclined (45 - 60°), we propose that the inner disk might be warped by a yet unseen (sub-)stellar companion, which may also explain the 2.77 day periodic variability of the spectral lines.

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A spectroscopic survey of Herbig Ae/Be stars with X-Shooter II: Accretion diagnostic lines

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The Herbig Ae/Be stars (HAeBes) allow an exploration of the properties of Pre-Main Sequence(PMS) stars above the low-mass range (<2 $M_\odot$) and those bordering the high-mass range (>8 $M_\odot$). This paper is the second in a series exploring accretion in 91 HAeBes with Very Large Telescope/X-shooter spectra. Equivalent width measurements are carried out on 32 different lines, spanning the UV to NIR, in order to obtain their line luminosities. The line luminosities were compared to accretion luminosities, which were determined directly from measurements of an UV-excess. When detected, emission lines always demonstrate a correlation with the accretion luminosity, regardless

of detection frequency. The average relationship between accretion luminosity and line luminosity is found to be $L_{\rm acc} \propto L_{\rm line}^{1.16\pm0.15}$. This is in agreement with the findings in Classical T Tauri stars, although the HAeBe relationship is generally steeper, particularly towards the Herbig Be mass range. Since all observed lines display a correlation with the accretion luminosity, all of them can be used as accretion tracers. This has increased the number of accretion diagnostic lines in HAeBes tenfold. However, questions still remain on the physical origin of each line, which may not be due to accretion.

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1.3mm polarized emission in the circumstellar disk of a massive protostar

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We present the first resolved observations of the 1.3mm polarized emission from the disk-like structure surrounding the high-mass protostar Cepheus A HW2. These CARMA data partially resolve the dust polarization, suggesting an uniform morphology of polarization vectors with an average position angle of 57° and an average polarization fraction of 2.0%. The distribution of the polarization vectors can be attributed to (1) the direct emission of magnetically aligned grains of dust by a uniform magnetic field, or (2) the pattern produced by the scattering of an inclined disk. We show that both models can explain the observations, and perhaps a combination of the two mechanisms produce the polarized emission. A third model including a toroidal magnetic field does not match the observations. Assuming scattering is the polarization mechanism, these observations suggest that during the first few 10000 years of high-mass star formation, grain sizes can grow from 1 to several 10s μm.

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Coevolution of Binaries and Gaseous Discs

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The recent discoveries of circumbinary planets by Kepler raise questions for contemporary planet formation models. Understanding how these planets form requires characterizing their formation environment, the circumbinary protoplanetary disc, and how the disc and binary interact and change as a result. The central binary excites resonances in the surrounding protoplanetary disc that drive evolution in both the binary orbital elements and in the disc. To probe how these interactions impact binary eccentricity and disc structure evolution, N-body smooth particle hydrodynamics (SPH) simulations of gaseous protoplanetary discs surrounding binaries based on Kepler 38 were run for 10^4 binary periods for several initial binary eccentricities. We find that nearly circular binaries weakly couple to the disc via a parametric instability and excite disc eccentricity growth. Eccentric binaries strongly couple to the disc causing eccentricity growth for both the disc and binary. Discs around sufficiently eccentric binaries that strongly couple to the disc develop an $m = 1$ spiral wave launched from the 1:3 eccentric outer Lindblad resonance (EOLR)

that corresponds to an alignment of gas particle longitude of periastrons. All systems display binary semimajor axis decay due to dissipation from the viscous disc.

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The fragmentation and stability of hierarchical structure in Serpens South

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Filamentary structures are ubiquitous in molecular clouds, and have been recently argued to play an important role in regulating the size and mass of embedded clumps through fragmentation and mass accretion. Here, we reveal the dynamical state and fragmentation of filamentary molecular gas associated with the Serpens South protocluster through analysis of wide ($\sim$4 $\times$ 4 pc) observations of NH_3 (1,1) and (2,2) inversion transitions with the Green Bank Telescope. Detailed modeling of the NH_3 lines reveals that the kinematics of the cluster and surrounding filaments are complex. We identify hierarchical structure using a dendrogram analysis of the NH_3 emission. The distance between neighbour structures that are embedded within the same parent structure is generally greater than expected from a spherical Jeans analysis, and is in better agreement with cylindrical fragmentation models. The NH_3 line width-size relation is flat, and average gas motions are sub- or trans-sonic over all physical scales observed. Subsonic regions extend far beyond the typical 0.1 pc scale previously identified in star-forming cores. As a result, we find a strong trend of decreasing virial parameter with increasing structure mass in Serpens South. Extremely low virial parameters on the largest scales probed by our data suggest that the previously observed, ordered magnetic field is insufficient to support the region against collapse, in agreement with large radial infall motions previously measured toward some of the filaments. A more complex magnetic field configuration in the dense gas, however, may be able to support the filaments.

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Water delivery from cores to disks: deuteration as a probe of the prestellar inheritance of H_2O

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We investigate the delivery of regular and deuterated forms of water from prestellar cores to circumstellar disks. We adopt a semi-analytical axisymmetric two-dimensional collapsing core model with post-processing gas-ice astrochemical simulations, in which a layered ice structure is considered. The physical and chemical evolutions are followed until the end of the main accretion phase. When mass averaged over the whole disk, a forming disk has a similar H_2O abundance and HDO/H_2O abundance ratio as their precollapse values (within a factor of 2), regardless of time in our models. Consistent with previous studies, our models suggest that interstellar water ice is delivered to forming disks without significant alteration. On the other hand, the local vertically averaged H_2O ice abundance and HDO/H_2O ice ratio can differ more, by up to a factor of several, depending on time and distance from a central star. Key parameters for the local variations are the fluence of stellar UV photons en route into the disk and the ice layered structure, the latter of which is mostly established in the prestellar stages. We also find that even if interstellar water ice is destroyed by stellar UV and (partly) reformed prior to disk entry, the HDO/H_2O ratio in reformed water ice is similar to the original value. This finding indicates that some caution is needed in discussions on the prestellar inheritance of H_2O based on comparisons between the observationally derived HDO/H_2O ratio in clouds/cores and that in disks/comets. Alternatively, we propose that the ratio of D_2O/HDO to HDO/H_2O better probes the prestellar inheritance of H_2O. It is also found that icy organics are more enriched in deuterium than water ice in forming disks. The differential deuterium fractionation in water and organics is inherited from the prestellar stages.

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Structure, Dynamics and Deuterium Fractionation of Massive Pre-Stellar Cores

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High levels of deuterium fraction in N_2H^+ are observed in some pre-stellar cores. Single-zone chemical models find that the timescale required to reach observed values ($D_{\rm frac}^{\rm N_2H^+} \equiv N_2D^+/N_2H^+ \geq 0.1$) is longer than the free-fall time, possibly ten times longer. Here, we explore the deuteration of turbulent, magnetized cores with 3D magnetohydrodynamics simulations. We use an approximate chemical model to follow the growth in abundances of N_2H^+ and N_2D^+. We then examine the dynamics of the core using each tracer for comparison to observations. We find that the velocity dispersion of the core as traced by N_2D^+ appears slightly sub-virial compared to predictions of the Turbulent Core Model of McKee & Tan, except at late times just before the onset of protostar formation. By varying the initial mass surface density, the magnetic energy, the chemical age, and the ortho-to-para ratio of H_2, we also determine the physical and temporal properties required for high deuteration. We find that low initial ortho-to-para ratios (≤ 0.01) and/or multiple free-fall times (≥ 3) of prior chemical evolution are necessary to reach the observed values of deuterium fraction in pre-stellar cores.

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A New Reference Chemical Composition for TMC-1

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Recent detections of complex organic molecules in dark clouds have rekindled interest in the astrochemical modeling of these environments. Because of its relative closeness and rich molecular complexity, TMC-1 has been extensively observed to study the chemical processes taking place in dark clouds. We use local thermodynamical equilibrium radiative transfer modeling coupled with a Bayesian statistical method which takes into account outliers to analyze the data from the Nobeyama spectral survey of TMC-1 between 8 and 50 GHz. We compute the abundance relative to molecular hydrogen of 57 molecules, including 19 isotopologues in TMC-1 along with their associated uncertainty. The new results are in general agreement with previous abundance determination from Ohishi & Kaifu and the values reported in the review from Agundez & Wakelam. However, in some cases, large opacity and low signal to noise effects allow only upper or lower limits to be derived, respectively.

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Non-linear dense core formation in the dark cloud L1517

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We present a solution for the observed core fragmentation of filaments in the Taurus L1517 dark cloud which previously could not be explained. Core fragmentation is a vital step for the formation of stars. Observations suggest a connection to the filamentary structure of the cloud gas, but it remains unclear which process is responsible. We show that the gravitational instability process of an infinite, isothermal cylinder can account for the exhibited fragmentation under the assumption that the perturbation grows on the dominant wavelength. We use numerical simulations with the code RAMSES, estimate observed column densities and line-of-sight velocities, and compare them to the observations. A critical factor for the observed fragmentation is that cores grow by redistributing mass within the filament and thus the density between the cores decreases over the fragmentation process. This often leads to wrong dominant wavelength estimates, as it is strongly dependent on the initial central density. We argue that non-linear effects also play an important role in the evolution of the fragmentation. Once the density perturbation grows above the critical line mass, non-linearity leads to an enhancement of the central core density in comparison to the analytical prediction. Choosing the correct initial conditions with perturbation strengths of around 20 per cent leads to inclination-corrected line-of-sight velocities and central core densities within the observational measurement error in a realistic evolution time.

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ALMA band 8 continuum emission from Orion Source I

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We have measured continuum flux densities of a high-mass protostar candidate, a radio source I in the Orion KL region (Orion Source I) using the Atacama Large Millimeter/Submillimeter Array (ALMA) at band 8 with an angular resolution of 0.1 arcsec. The continuum emission at 430, 460, and 490 GHz associated with Source I shows an elongated structure along the northwest-southeast direction perpendicular to the so-called low-velocity bipolar outflow. The deconvolved size of the continuum source, 90 au×20 au, is consistent with those reported previously at other millimeter/submillimeter wavelength. The flux density can be well fitted to the optically thick black-body spectral energy distribution (SED), and the brightness temperature is evaluated to be 700-800 K. It is much lower than that in the case of proton-electron or H^- free-free radiations. Our data are consistent with the latest ALMA results by Plambeck & Wright (2016), in which the continuum emission have been proposed to arise from the edge-on circumstellar disk via thermal dust emission, unless the continuum source consists of an unresolved structure with the smaller beam filling factor.

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Formation of dust-rich planetesimals from sublimated pebbles inside of the snow line

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Content. For up to a few millions of years, pebbles must provide a quasi-steady inflow of solids from the outer parts of protoplanetary disks to their inner regions.
Aims. We wish to understand how a significant fraction of the pebbles grows into planetesimals instead of being lost to the host star.
Methods. We examined analytically how the inward flow of pebbles is affected by the snow line and under which conditions dust-rich (rocky) planetesimals form. When calculating the inward drift of solids that is due to gas drag, we included the back-reaction of the gas to the motion of the solids.
Results. We show that in low-viscosity protoplanetary disks (with a monotonous surface density similar to that of the minimum-mass solar nebula), the flow of pebbles does not usually reach the required surface density to form planetesimals by streaming instability. We show, however, that if the pebble-to-gas-mass flux exceeds a critical value, no steady solution can be found for the solid-to-gas ratio. This is particularly important for low-viscosity disks ($\alpha < 10^{-3}$) where we show that inside of the snow line, silicate-dust grains ejected from sublimating pebbles can accumulate, eventually leading to the formation of dust-rich planetesimals directly by gravitational instability.
Conclusions. This formation of dust-rich planetesimals may occur for extended periods of time, while the snow line sweeps from several au to inside of 1 au. The rock-to-ice ratio may thus be globally significantly higher in planetesimals and planets than in the central star.

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Discovery of a Hot Corino in the Bok Globule B335

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We report the first evidence of a hot corino in a Bok globule. This is based on the ALMA observations in the 1.2 mm band toward the low-mass Class 0 protostar IRAS 19347+0727 in B335. Saturated complex organic molecules (COMs), CH_3CHO, $HCOOCH_3$, and NH_2CHO, are detected in a compact region within a few 10 au around the protostar. Additionally, CH_3OCH_3, C_2H_5OH, C_2H_5CN, and CH_3COCH_3 are tentatively detected. Carbon-chain related molecules, CCH and c-C_3H_2, are also found in this source, whose distributions are extended over a few 100 au scale. On the other hand, sulfur-bearing molecules CS, SO, and SO_2, have both compact and extended components. Fractional abundances of the COMs relative to H_2 are found to be comparable to those in known hot-corino sources. Though the COMs lines are as broad as 5-8 km s^{-1}, they do not show obvious rotation motion in the present observation. Thus, the COMs mainly exist in bf a structure whose distribution is much smaller than the synthesized beam ($0.58' \times 0.52'$).

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History of the solar-type protostar IRAS16293−2422 as told by the cyanopolyynes

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Cyanopolyynes are chains of carbon atoms with an atom of hydrogen and a CN group on either side. They are detected almost everywhere in the ISM, as well as in comets. In the past, they have been used to constrain the age of some molecular clouds, since their abundance is predicted to be a strong function of time. We present an extensive study of the cyanopolyynes distribution in the solar-type protostar IRAS16293−2422 based on TIMASSS IRAM-30m observations. The goals are (i) to obtain a census of the cyanopolyynes in this source and of their isotopologues; (ii) to derive how their abundance varies across the protostar envelope; and (iii) to obtain constraints on the history of IRAS16293−2422. We detect several lines from HC_3N and HC_5N, and report the first detection of DC_3N, in a solar-type protostar. We found that the HC_3N abundance is roughly constant ($\sim 1.3 \times 10^{-11}$) in the outer cold envelope of IRAS16293−2422, and it increases by about a factor 100 in the inner region where $T_{\rm dust} > 80$ K. The HC_5N has an abundance similar to HC_3N in the outer envelope and about a factor of ten lower in the inner region. The HC_3N

abundance derived in the inner region, and where the increase occurs, also provide strong constraints on the time taken for the dust to warm up to 80 K, which has to be shorter than $\sim 10^3$–10^4 yr. Finally, the cyanoacetylene deuteration is about 50% in the outer envelope and <5% in the warm inner region. The relatively low deuteration in the warm region suggests that we are witnessing a fossil of the HC_3N abundantly formed in the tenuous phase of the pre-collapse and then frozen into the grain mantles at a later phase. The accurate analysis of the cyanopolyynes in IRAS16293−2422 unveils an important part of its past story. It tells us that IRAS16293−2422 underwent a relatively fast ($<10^5$ yr) collapse and a very fast ($<10^3$–10^4 yr) warming up of the cold material to 80 K.

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Submillimeter polarization observation of the protoplanetary disk around HD 142527

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We present the polarization observations toward the circumstellar disk around HD 142527 by using Atacama Large Millimeter/submillimeter Array (ALMA) at the frequency of 343 GHz. The beam size is 0.|!′′51 × 0.|!′′44, which corresponds to the spatial resolution of $\sim 71 \times 62$ AU. The polarized intensity displays a ring-like structure with a peak located on the east side with a polarization fraction of $P = 3.26 \pm 0.02\%$, which is different from the peak of the continuum emission from the northeast region. The polarized intensity is significantly weaker at the peak of the continuum where $P = 0.220 \pm 0.010\%$. The polarization vectors are in the radial direction in the main ring of the polarized intensity, while there are two regions outside at the northwest and northeast areas where the vectors are in the azimuthal direction. If the polarization vectors represent the magnetic field morphology, the polarization vectors indicate the toroidal magnetic field configuration on the main ring and the poloidal fields outside. On the other hand, the flip of the polarization vectors is predicted by the self-scattering of thermal dust emission due to the change of the direction of thermal radiation flux. Therefore, we conclude that self-scattering of thermal dust emission plays a major role in producing polarization at millimeter wavelengths in this protoplanetary disk. Also, this puts a constraint on the maximum grain size to be approximately 150 μm if we assume compact spherical dust grains.

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The Galactic Center Molecular Cloud Survey. I. A Steep Linewidth-Size Relation & Suppression of Star Formation

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The Central Molecular Zone (CMZ; inner ∼200 pc) of the Milky Way is a star formation (SF) environment with very extreme physical properties. Exploration of SF in this region is important because (i) this region allows us to test models of star formation under exceptional conditions, and (ii) the CMZ clouds might be suitable to serve as templates to understand the physics of starburst galaxies in the nearby and the distant universe. For this reason we launched the Galactic Center Molecular Cloud Survey (GCMS), the first systematic study that resolves all major CMZ clouds at interferometer angular resolution (i.e., a few arc seconds). Here we present initial results based on observations with the Submillimeter Array (SMA) and the Atacama Pathfinder Experiment (APEX). Our study is complemented by dust emission data from the Herschel Space Telescope and a comprehensive literature survey of CMZ star formation activity. Our research reveals (i) an unusually steep linewidth-size relation, $\sigma(v) \propto r_{\rm eff}^{0.66\pm0.18}$, down to velocity dispersions ∼0.6 km s^{-1} at 0.1 pc scale. This scaling law potentially results from the decay of gas motions to transonic velocities in strong shocks. The data also show that, relative to dense gas in the solar neighborhood, (ii) star formation is suppressed by factors $\gtrsim$10 in individual CMZ clouds. This observation encourages exploration of processes that can suppress SF inside dense clouds for a significant period of time.

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Tracing water vapor and ice during dust growth

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The processes that govern the evolution of dust and water (in the form of vapor or ice) in protoplanetary disks are intimately connected. We have developed a model that simulates dust coagulation, dust dynamics (settling, turbulent mixing), vapor diffusion, and condensation/sublimation of volatiles onto grains in a vertical column of a protoplanetary disk. We employ the model to study how dust growth and dynamics influence the vertical distribution of water vapor and water ice in the region just outside the radial snowline. Our main finding is that coagulation (boosted by the enhanced stickiness of icy grains) and the ensuing vertical settling of solids results in water vapor being depleted, but not totally removed, from the region above the snowline on a timescale commensurate with the vertical turbulent mixing timescale. Depending on the strength of the turbulence and the temperature, the depletion can reach factors of up to ∼50 in the disk atmosphere. In our isothermal column, this vapor depletion results in the vertical snowline moving closer to the midplane (by up to 2 gas scale heights) and the gas-phase C/O ratio above the vertical snowline increasing. Our findings illustrate the importance of dynamical effects and the need for understanding coevolutionary dynamics of gas and solids in planet-forming environments.

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A Young Eclipsing Binary and its Luminous Neighbors in the Embedded Star Cluster Sh 2-252E

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We present a photometric and light curve analysis of an eccentric eclipsing binary in the K2 Campaign 0 field that resides in Sh 2-252E, a young star cluster embedded in an H II region. We describe a spectroscopic investigation of the

three brightest stars in the crowded aperture to identify which is the binary system. We find that none of these stars are components of the eclipsing binary system, which must be one of the fainter nearby stars. These bright cluster members all have remarkable spectra: Sh 2-252a (EPIC 202062176) is a B0.5 V star with razor sharp absorption lines, Sh 2-252b is a Herbig A0 star with disk-like emission lines, and Sh 2-252c is a pre-main sequence star with very red color.

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Hot methanol from the inner region of the HH 212 protostellar system

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The mechanisms leading to the formation of disks around young stellar objects (YSOs) and to the launching of the associated jets are crucial to the understanding of the earliest stages of star and planet formation. HH 212 is a privileged laboratory to study a pristine jet-disk system. Therefore we investigate the innermost region (<100 AU) around the HH 212-MM1 protostar through ALMA band 7 observations of methanol. The 8 GHz bandwidth spectrum towards the peak of the continuum emission of the HH 212 system reveals at least 19 transitions of methanol. Several of these lines (among which several vibrationally excited lines in the v_t=1,2 states) have upper energies above 500 K. They originate from a compact (<135 AU in diameter), hot (∼295 K) region elongated along the direction of the SiO jet. We performed a fit in the *uv* plane of various velocity channels of the strongest high-excitation lines. The blue- and red-shifted velocity centroids are shifted roughly symmetrically on either side of the jet axis, indicating that the line-of-sight velocity beyond 0.7 km s^{-1} from systemic is dominated by rotational motions. The velocity increases moving away from the protostar further indicating that the emission of methanol is not associated with a Keplerian disk or rotating-infalling cavity, and it is more likely associated with outflowing gas. We speculate that CH_3OH traces a disk wind gas accelerated at the base. The launching region would be at a radius of a few astronomical units from the YSO.

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Criteria for gravitational instability and quasi-isolated gravitational collapse in turbulent medium

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We study the evolution of structures in turbulent, self-gravitating media, and present an analytical criterion $M_{\rm crit} \approx \epsilon_{\rm cascade}^{2/3}\eta^{-2/3}G^{-1}l^{5/3}$ (where $M_{\rm crit}$ is the critical mass, l is the scale, $\epsilon_{\rm cascade} \approx \eta\sigma_{\rm v}^3/l$ is the turbulence energy dissipation rate of the ambient medium, G is the gravitational constant, $\sigma_{\rm v}$ is the velocity dispersion, l is the scale and $\eta \approx 0.2$ is an efficiency parameter) for an object to undergo quasi-isolated gravitational collapse. The criterion also defines the critical scale ($l_{\rm crit} \approx \epsilon_{\rm cascade}^{1/2}\eta^{-1/2}G^{-3/4}\rho^{-3/4}$) for turbulent gravitational instability to develop. The analytical

formalism explains the size dependence of the masses of the progenitors of star clusters ($M_{\rm cluster} \sim R_{\rm cluster}^{1.67}$) in our Galaxy.

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A Survey for New Members of the Taurus Star-Forming Region with the Sloan Digital Sky Survey

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Previous studies have found that $\sim$1 deg^2 fields surrounding the stellar aggregates in the Taurus star-forming region exhibit a surplus of solar-mass stars relative to denser clusters like IC 348 and the Orion Nebula Cluster. To test whether this difference reflects mass segregation in Taurus or a variation in the IMF, we have performed a survey for members of Taurus across a large field ($\sim$40 deg^2) that was imaged by the Sloan Digital Sky Survey (SDSS). We obtained optical and near-infrared spectra of candidate members identified with those images and the Two Micron All Sky Survey, as well as miscellaneous candidates that were selected with several other diagnostics of membership. We have classified 22 of the candidates as new members of Taurus, which includes one of the coolest known members (M9.75). Our updated census of members within the SDSS field shows a surplus of solar-mass stars relative to clusters, although it is less pronounced than in the smaller fields towards the stellar aggregates that were surveyed for previously measured mass functions in Taurus. In addition to spectra of our new members, we include in our study near-IR spectra of roughly half of the known members of Taurus, which are used to refine their spectral types and extinctions. We also present an updated set of near-IR standard spectra for classifying young stars and brown dwarfs at M and L types.

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The compact Hα emitting regions of the Herbig Ae/Be stars HD 179218 and HD 141569 from CHARA spectro-interferometry

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This work presents CHARA/VEGA Hα spectro-interferometry (R $\sim$ 6000, and λ/2B $\sim$ 1 *mas*) of HD 179218 and HD 141569, doubling the sample of Herbig Ae/Be (HAeBe) stars for which this type of observations is available so far. The observed Hα emission is spatially unresolved, indicating that the size of the Hα emitting region is smaller than $\sim$ 0.21 and 0.12 *au* for HD 179218 and HD 141529 ($\sim$ 15 and 16 R$_*$, respectively). This is smaller than for the two other HAeBes previously observed with the same instrumentation. Two different scenarios have been explored in order to explain the compact line emitting regions. A hot, several thousand K, blackbody disc is consistent with the observations of HD 179218 and HD 141569. Magnetospheric accretion (MA) is able to reproduce the bulk of the Hα emission shown by HD 179218, confirming previous estimates from MA shock modelling with a mass accretion rate of 10^{-8} M$_\odot$ yr^{-1}, and an inclination to the line of sight between 30 and 50°. The Hα profile of HD 141569 cannot be fitted from MA due to the high rotational velocity of this object. Putting the CHARA sample together, a variety of scenarios is required to explain the Hα emission in HAeBe stars -compact or extended, discs, accretion, and winds-, in agreement with previous Brγ spectro-interferometric observations.

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The effect of radiative feedback on disc fragmentation

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Protostellar discs may become massive enough to fragment producing secondary low-mass objects: planets, brown dwarfs and low-mass stars. We study the effect of radiative feedback from such newly-formed secondary objects using radiative hydrodynamic simulations. We compare the results of simulations without any radiative feedback from secondary objects with those where two types of radiative feedback are considered: (i) continuous, and (ii) episodic. We find that: (i) continuous radiative feedback stabilizes the disc and suppresses further fragmentation, reducing the number secondary objects formed; (ii) episodic feedback from secondary objects heats and stabilises the disc when the outburst occurs, but shortly after the outburst stops, the disc becomes unstable and fragments again. However, fewer secondary objects are formed compared to the the case without radiative feedback. We also find that the mass growth of secondary objects is mildly suppressed due to the effect of their radiative feedback. However, their mass growth also depends on where they form in the disc and on their subsequent interactions, such that their final masses are not drastically different from the case without radiative feedback. We find that the masses of secondary objects formed by disc fragmentation are from a few M_J to a few 0.1 $M_\odot$. Planets formed by fragmentation tend to be ejected from the disc. We conclude that planetary-mass objects on wide orbits (wide-orbit planets) are unlikely to form by disc fragmentation. Nevertheless, disc fragmentation may be a significant source of free-floating planets and brown dwarfs.

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Protoplanetary Disks in the Hostile Environment of Carina

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We report the first direct imaging of protoplanetary disks in the star-forming region of Carina, the most distant, massive cluster in which disks have been imaged. Using the Atacama Large Millimeter/sub-millimeter Array (ALMA), disks are observed around two young stellar objects (YSOs) that are embedded inside evaporating gaseous globules and exhibit jet activity. The disks have an average size of 120 AU and total masses of 30 and 50 $M_{\rm Jup}$. Given the measured masses, the minimum timescale required for planet formation ($\sim 1-2$ Myr) and the average age of the Carina population ($\sim 1-4$ Myr), it is plausible that young planets are present or their formation is currently ongoing in these disks. The non-detection of millimeter emission above the 4σ threshold ($\sim 7M_{\rm Jup}$) in the core of the massive cluster Trumpler 14, an area containing previously identified proplyd candidates, suggest evidence for rapid photo-evaporative disk destruction in the cluster's harsh radiation field. This would prevent the formation of giant gas planets in disks located in the cores of Carina's dense sub-clusters, whereas the majority of YSO disks in the wider Carina region remain unaffected by external photo-evaporation.

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Three-dimensional Shock Structure of Orion KL Outflow with IGRINS

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We report a study of the three-dimensional (3D) outflow structure of a $15' \times 13'$ area around H_2 peak 1 in Orion KL with slit-scan observations (13 slits) using the Immersion Grating Infrared Spectrograph. The datacubes, with high velocity-resolution ($\sim$ 7.5 km s^{-1}) provide high contrast imaging within ultra-narrow bands, and enable the detection of the main stream of the previously reported H_2 outflow fingers. We identified 31 distinct fingers in H_2 1−0 S(1) λ2.122 μm emission. The line profile at each finger shows multiple-velocity peaks with a strong low-velocity component around the systemic velocity at $V_{\rm LSR}$ = +8 km s^{-1} and high velocity emission ($|V_{\rm LSR}|$ = 45−135 km s^{-1}) indicating a typical bow-shock. The observed radial velocity gradients of $\sim$ 4 km s^{-1} arcsec^{-1} agree well with the velocities inferred from large-scale proper motions, where the projected motion is proportional to distance from a common origin. We construct a conceptual 3D map of the fingers with the estimated inclination angles of 57°−74°. The extinction difference ($\Delta A_{\rm v} > 10$ mag) between blueshifted and redshifted fingers indicates high internal extinction. The extinction, the overall angular spread and scale of the flow argue for an ambient medium with very high density (10^5-10^6 cm^{-3}), consistent with molecular line observations of the OMC core. The radial velocity gradients and the 3D distributions of the fingers together support the hypothesis of simultaneous, radial explosion of the Orion KL outflow.

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Dense core properties in the Infrared Dark cloud G14.225-0.506 revealed by ALMA

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We have performed a dense core survey toward the Infrared Dark Cloud G14.225-0.506 at 3 mm continuum emission with the Atacama Large Millimeter/Submillimeter Array (ALMA). This survey covers the two hub-filament systems with an angular resolution of $\sim$ 3 *arcsec* ($\sim$ 0.03 pc). We identified 48 dense cores. Twenty out of the 48 cores are protostellar due to their association with young stellar objects (YSOs) and/or X-ray point-sources, while the other 28 cores are likely prestellar and unrelated with known IR or X-ray emission. Using APEX 870 μm continuum emission, we also identified the 18 clumps hosting these cores. Through virial analysis using the ALMA N_2H^+ and VLA/Effelsberg NH_3 molecular line data, we found a decreasing trend in the virial parameter with decreasing scales from filaments to clumps, and then to cores. The virial parameters of $0.1 - 1.3$ in cores, indicate that cores are likely undergoing dynamical collapse. The cumulative Core Mass Function (CMF) for the prestellar cores candidates has a power law index of $\alpha = 1.6$, with masses ranging from 1.5 to 22 $M_{\odot}$. We find no massive prestellar or protostellar cores. Previous studies suggest that massive O-tpye stars have not been produced yet in this region. Therefore, high-mass stars should be formed in the prestellar cores by accreting a significant amount of gas from the surrounding medium. Another possibility is that low-mass YSOs become massive by accreting from their parent cores that are fed by filaments. These two possibilities might be consistent with the scenario of global hierarchical collapse.

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The Gould's Belt Distances Survey (GOBELINS) III. The distance to the Serpens/Aquila Molecular Complex

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We report on new distances and proper motions to seven stars across the Serpens/Aquila complex. The observations were obtained as part of the Gould's Belt Distances Survey (GOBELINS) project between September 2013 and April 2016 with the Very Long Baseline Array (VLBA). One of our targets is the proto-Herbig AeBe object EC 95, which is a binary system embedded in the Serpens Core. For this system, we combined the GOBELINS observations with previous VLBA data to cover a total period of ∼8 years, and derive the orbital elements and an updated source distance. The individual distances to sources in the complex are fully consistent with each other, and the mean value corresponds to a distance of 436.0±9.2 p1c for the Serpens/W40 complex. Given this new evidence, we argue that Serpens Main, W40 and Serpens South are physically associated and form a single cloud structure.

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Spiral Density Waves in a Young Protoplanetary Disk

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Gravitational forces are expected to excite spiral density waves in protoplanetary disks, disks of gas and dust orbiting young stars. However, previous observations that showed spiral structure were not able to probe disk midplanes, where most of the mass is concentrated and where planet formation takes place. Using the Atacama Large Millimeter/submillimeter Array we detected a pair of trailing symmetric spiral arms in the protoplanetary disk surrounding the young star Elias 2-27. The arms extend to the disk outer regions and can be traced down to the midplane. These millimeter-wave observations also reveal an emission gap closer to the star than the spiral arms. We argue that the observed spirals trace shocks of spiral density waves in the midplane of this young disk.

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Can dead zones create structures like a transition disk?

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Context: Regions of low ionisation where the activity of the magneto-rotational instability is suppressed, the so-called dead zones, have been suggested to explain gaps and asymmetries of transition disks. Dead zones are therefore a potential cause for the observational signatures of transition disks without requiring the presence of embedded planets.
Aims: We investigate the gas and dust evolution simultaneously assuming simplified prescriptions for a dead zone and a magnetohydrodynamic (MHD) wind acting on the disk. We explore whether the resulting gas and dust distribution can create signatures similar to those observed in transition disks.

Methods: We imposed a dead zone and/or an MHD wind in the radial evolution of gas and dust in protoplanetary disks. For the dust evolution, we included the transport, growth, and fragmentation of dust particles. To compare with observations, we produced synthetic images in scattered optical light and in thermal emission at mm wavelengths.
Results: In all models with a dead zone, a bump in the gas surface density is produced that is able to efficiently trap large particles ($\gtrsim$1 mm) at the outer edge of the dead zone. The gas bump reaches an amplitude of a factor of ~ 5, which can be enhanced by the presence of an MHD wind that removes mass from the inner disk. While our 1D simulations suggest that such a structure can be present only for $\sim$1 Myr, the structure may be maintained for a longer time when more realistic 2D/3D simulations are performed. In the synthetic images, gap-like low-emission regions are seen at scattered light and in thermal emission at mm wavelengths, as previously predicted in the case of planet-disk interaction.
Conclusions: Main signatures of transition disks can be reproduced by assuming a dead zone in the disk, such as gap-like structure in scattered light and millimetre continuum emission, and a lower gas surface density within the dead zone. Previous studies showed that the Rossby wave instability can also develop at the edge of such dead zones, forming vortices and also creating asymmetries.

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The Multiple Young Stellar Objects of HBC 515: An X-ray and Millimeter-wave Imaging Study in (Pre-main Sequence) Diversity

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We present Chandra X-ray Observatory and Submillimeter Array (SMA) imaging of HBC 515, a system consisting of multiple young stellar objects (YSOs). The five members of HBC 515 represent a remarkably diverse array of YSOs, ranging from the low-mass Class I/II protostar HBC 515B, through Class II and transition disk objects (HBC 515D and C, respectively), to the "diskless", intermediate- mass, pre-main sequence binary HBC 515A. Our Chandra/ACIS imaging establishes that all five components are X-ray sources, with HBC 515A - a subarcsecond-separation binary that is partially resolved by Chandra - being the dominant X-ray source. We detect an X-ray flare associated with HBC 515B. In the SMA imaging, HBC 515B is detected as a strong 1.3 mm continuum emission source; a second, weaker mm continuum source is coincident with the position of the transition disk object HBC 515C. These results strongly support the protostellar nature of HBC 515B, and firmly establish HBC 515A as a member of the rare class of relatively massive, X-ray luminous "weak-lined T Tauri stars" that are binaries and have shed their disks at very early stages of pre-MS evolution. The coexistence of two such disparate objects within a single, presumably coeval multiple YSO system highlights the influence of pre- MS star mass, binarity, and X-ray luminosity in regulating the lifetimes of circumstellar, planet-forming disks and the timescales of star-disk interactions.

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Young Stars with SALT

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We present a spectroscopic and kinematic analysis of 79 nearby M dwarfs in 77 systems. All are low-proper-motion southern hemisphere objects and were identified in a nearby star survey with a demonstrated sensitivity to young stars. Using low-resolution optical spectroscopy from the Red Side Spectrograph (RSS) on the South African Large Telescope (SALT), we have determined radial velocities, Hα, Lithium 6708Å, and Potassium 7699Å equivalent widths linked to age and activity, and spectral types for all our targets. Combined with astrometric information from literature sources, we identify 44 young stars. Eighteen are previously known members of moving groups within 100 parsecs of the Sun. Twelve are new members, including one member of the TW Hydra moving group, one member of the 32 Orionis moving group, nine members of Tucana-Horologium, one member of Argus, and two new members of AB Doradus. We also find fourteen young star systems that are not members of any known groups. The remaining 33 star systems do not appear to be young. This appears to be evidence of a new population of nearby young stars not related to the known nearby young moving groups.

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On the chemical ladder of esters. Detection and formation of ethyl formate in the W51 e2 hot molecular core

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The detection of organic molecules with increasing complexity and potential biological relevance is opening the possibility to understand the formation of the building blocks of life in the interstellar medium. One of the families of molecules with astrobiological interest are the esters, whose simplest member, methyl formate, is rather abundant in star-forming regions. The next step in the chemical complexity of esters is ethyl formate, C_2H_5OCHO. Only two detections of this species have been reported so far, which strongly limits our understanding of how complex molecules are formed in the interstellar medium. We have searched for ethyl formate towards the W51 e2 hot molecular core, one of the most chemically rich sources in the Galaxy and one of the most promising regions to study prebiotic chemistry, especially after the recent discovery of the P−O bond, key in the formation of DNA. We have analyzed a spectral line survey towards the W51 e2 hot molecular core, which covers 44 GHz in the 1, 2 and 3 mm bands, carried out with the IRAM 30m telescope. We report the detection of the trans and gauche conformers of ethyl formate. A Local Thermodynamic Equilibrium analysis indicates that the excitation temperature is 78±10 K and that the two conformers have similar source-averaged column densities of $(2.0\pm0.3)\times10^{16}$ cm^{-2} and an abundance of $\sim10^{-8}$. We compare the observed molecular abundances of ethyl formate with different competing chemical models based on grain surface and gas-phase chemistry. We propose that grain-surface chemistry may have a dominant role in the formation of ethyl formate (and other complex organic molecules) in hot molecular cores, rather than reactions in the gas phase.

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Momentum-driven outflow emission from an O-type YSO: Comparing the radio jet with the molecular outflow

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Aims: We want to study the physical properties of the ionized jet emission in the vicinity of an O-type young stellar object (YSO), and estimate how efficient is the transfer of energy and momentum from small- to large-scale outflows.
Methods: We conducted Karl G. Jansky Very Large Array (VLA) observations, at both 22 and 45 GHz, of the compact and faint radio continuum emission in the high-mass star-forming region G023.01-00.41, with an angular resolution between $0.3''$ and $0.1''$, and a thermal rms of the order of 10 μJy/beam.
Results: We discovered a collimated thermal (bremsstrahlung) jet emission, with a radio luminosity (L_{rad}) of 24 mJy kpc^2 at 45 GHz, in the inner 1000 AU from an O-type YSO. The radio thermal jet has an opening angle of 44 degrees and brings a momentum rate of 8 10^{-3} $M_\odot$ yr^{-1} km/s. By combining the new data with previous observations of the molecular outflow and water maser shocks, we can trace the outflow emission from its driving source through the molecular clump, across more than two orders of magnitude in length (500 AU-0.2 pc). We find that the momentum-transfer efficiency, between the inner jet emission and the extended outflow of entrained ambient gas, is near unity. This result suggests that the large-scale flow is swept-up by the mechanical force of the radio jet emission, which originates in the inner 1000 AU from the high-mass YSO.

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Magnetically Dominated Parallel Interstellar Filaments at the Infrared Dark Cloud G14.225-0.506

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The G14.225-0.506 infrared dark cloud (IRDC G14.2) displays a remarkable complex of parallel dense molecular filaments projected on the plane of the sky. Previous dust emission and molecular-line studies have speculated whether magnetic fields could have played an important role in the formation of such long-shaped structures, which are hosts to numerous young stellar sources. In this work we have conducted a vast polarimetric survey at optical and near-infrared wavelengths in order to study the morphology of magnetic field lines in IRDC G14.2 through the observation of background stars. The orientation of interstellar polarization, which traces magnetic field lines, is perpendicular to most of the filamentary features within the cloud. Additionally, the larger-scale molecular cloud as a whole exhibits an elongated shape also perpendicular to magnetic fields. Estimates of magnetic field strengths indicate values in the range $320-550\,\mu$G, which allows sub-alfvénic conditions, but does not prevent the gravitational collapse of hub-filament structures, which in general are close to the critical state. These characteristics suggest that magnetic fields played the main role in regulating the collapse from large to small scales, leading to the formation of series of parallel elongated structures. The morphology is also consistent with numerical simulations that show how gravitational instabilities develop under strong magnetic fields. Finally, the results corroborate the hypothesis that a strong support from internal magnetic fields might explain why the cloud seems to be contracting on a time scale $2-3$ times larger than what is expected from a free-fall collapse.

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Probing the magnetic fields in L1415 and L1389

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We present the R-band polarimetric results towards two nebulae L1415 and L1389 containing low luminosity stars. Aim of this study is to understand the role played by magnetic fields in formation of low luminosity objects. Linear polarization arise due to dichroism of the background starlight projected on the cloud providing the plane-of-the sky magnetic field orientation. The offsets between mean magnetic field directions obtained towards L1415 and L1389 and the projected outflow axes are found to be 35° and 12°, respectively. The offset between cloud minor axes and mean envelope magnetic field direction in L1415 and L1389 are 50° and 87°, respectively. To estimate the magnetic field strength by using the updated Chandrasekhar-Fermi relation, we obtained the ^{12}CO(J=1–0) line velocity dispersion value towards L1415 cloud using the TRAO single dish observations. The values of $B_{\rm pos}$ in L1415 and L1389 are found to be 28 μG and 149 μG using CF technique and 23 $^{\mu}$G and 140 μG using structure function analysis, respectively. The values of $B_{\rm pos}$ in these clouds are found to be consistent using both the techniques. By combining the present results with those obtained from our previous study of magnetic fields in cores with VeLLOs, we attempt to improve the sample of cores with low luminosity protostars and bridge the gap between the understanding of importance of magnetic fields in cores with VeLLOs and low luminosity protostars. The Results of this work and that of our previous work show that the outflow directions are aligned with envelope magnetic fields of the clouds.

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Circumplanetary disks around young giant planets: a comparison between core-accretion and disk instability

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Circumplanetary disks can be found around forming giant planets, regardless of whether core accretion or gravitational instability built the planet. We carried out state-of-the-art hydrodynamical simulations of the circumplanetary disks for both formation scenarios, using as similar initial conditions as possible to unveil possible intrinsic differences in the circumplanetary disk mass and temperature between the two formation mechanisms. We found that the circumplanetary disks mass linearly scales with the circumstellar disk mass. Therefore, in an equally massive protoplanetary disk, the circumplanetary disks formed in the disk instability model can be only a factor of eight more massive than their core-accretion counterparts. On the other hand, the bulk circumplanetary disk temperature differs by more than an order of magnitude between the two cases. The subdisks around planets formed by gravitational instability have a characteristic temperature below 100 K, while the core accretion circumplanetary disks are hot, with temperatures even greater than 1000 K when embedded in massive, optically thick protoplanetary disks. We explain how this difference can be understood as the natural result of the different formation mechanisms. We argue that the different temperatures should persist up to the point when a full-fledged gas giant forms via disk instability, hence our result provides a convenient criteria for observations to distinguish between the two main formation scenarios by measuring the bulk temperature in the planet vicinity.

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Kinetic temperature of massive star forming molecular clumps measured with formaldehyde

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For a general understanding of the physics involved in the star formation process, measurements of physical parameters such as temperature and density are indispensable. The chemical and physical properties of dense clumps of molecular clouds are strongly affected by the kinetic temperature. Therefore, this parameter is essential for a better understanding of the interstellar medium. Formaldehyde, a molecule which traces the entire dense molecular gas, appears to be the most reliable tracer to directly measure the gas kinetic temperature.We aim to determine the kinetic temperature with spectral lines from formaldehyde and to compare the results with those obtained from ammonia lines for a large number of massive clumps.Three 218 GHz transitions ($J_{K_A K_C}$=3_{03}–2_{02}, 3_{22}–2_{21}, and 3_{21}–2_{20}) of para-H_2CO were observed with the 15m James Clerk Maxwell Telescope (JCMT) toward 30 massive clumps of the Galactic disk at various stages of high-mass star formation. Using the RADEX non-LTE model, we derive the gas kinetic temperature modeling the measured para-H_2CO 3_{22}–2_{21}/3_{03}–$2_{02}$and 3_{21}–2_{20}/3_{03}–2_{02} ratios. The gas kinetic temperatures derived from the para-H_2CO (3_{21}–2_{20}/3_{03}–2_{02}) line ratios range from 30 to 61 K with an average of 46 K. A comparison of kinetic temperature derived from para-H_2CO, NH_3, and the dust emission indicates that in many cases para-H_2CO traces a similar kinetic temperature to the NH_3 (2,2)/(1,1) transitions and the dust associated with the HII regions. Distinctly higher temperatures are probed by para-H_2CO in the clumps associated with outflows/shocks. Kinetic temperatures obtained from para-H_2CO trace turbulence to a higher degree than NH_3 (2,2)/(1,1) in the massive clumps. The non-thermal velocity dispersions of para-H_2CO lines are positively correlated with the gas kinetic temperature. The massive clumps are significantly influenced by supersonic non-thermal motions.

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A Triple Protostar System Formed via Fragmentation of a Gravitationally Unstable Disk

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Binary and multiple star systems are a frequent outcome of the star formation process(Duchene & Kraus 2013; Reipurth et al. 2014), and as a result, almost half of all sun-like stars have at least one companion star. Theoretical studies indicate that there are two main pathways that can operate concurrently to form binary/multiple star systems:

large scale fragmentation of turbulent gas cores and filaments (Fischer et al. 2004; Padoan et al. 2004) or smaller scale fragmentation of a massive protostellar disk due to gravitational instability (Adams et al. 1989; Bonnell & Bate 1994) Observational evidence for turbulent fragmentation on scales of >1000 AU has recently emerged (Pineda et al. 2015; Lee et al. 2015). Previous evidence for disk fragmentation was limited to inferences based on the separations of more-evolved pre-main sequence and protostellar multiple systems (Connelley et al. 2008; Kraus & Hillenbrand 2011; Takakuwa et al. 2012; Tobin et al. 2016). The triple protostar system L1448 IRS3B is an ideal candidate to search for evidence of disk fragmentation. L1448 IRS3B is in an early phase of the star formation process, likely less than 150,000 years in age (Lee et al. 2015), and all protostars in the system are separated by <200 AU. Here we report observations of dust and molecular gas emission that reveal a disk with spiral structure surrounding the three protostars. Two protostars near the center of the disk are separated by 61 AU, and a tertiary protostar is coincident with a spiral arm in the outer disk at a 183 AU separation (Tobin et al. 2016). The inferred mass of the central pair of protostellar objects is $\sim$1 $M_\odot$, while the disk surrounding the three protostars has a total mass of $\sim$0.30 $M_\odot$. The tertiary protostar itself has a minimum mass of $\sim$0.085 M$\odot$. We demonstrate that the disk around L1448 IRS3B appears susceptible to disk fragmentation at radii between 150 AU and 320 AU, overlapping with the location of the tertiary protostar. This is consistent with models for a protostellar disk that has recently undergone gravitational instability, spawning one or two companion stars.

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Three radial gaps in the disk of TW Hydrae imaged with SPHERE

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We present scattered light images of the TW Hya disk performed with SPHERE in PDI mode at 0.63, 0.79, 1.24 and 1.62 μm. We also present H2/H3-band ADI observations. Three distinct radial depressions in the polarized intensity distribution are seen, around 85, 21, and 6 au. The overall intensity distribution has a high degree of azimuthal symmetry; the disk is somewhat brighter than average towards the South and darker towards the North-West. The ADI observations yielded no signifiant detection of point sources in the disk.
Our observations have a linear spatial resolution of 1 to 2 au, similar to that of recent ALMA dust continuum observations. The sub-micron sized dust grains that dominate the light scattering in the disk surface are strongly coupled to the gas. We created a radiative transfer disk model with self-consistent temperature and vertical structure iteration and including grain size-dependent dust settling. This method may provide independent constraints on the gas distribution at higher spatial resolution than is feasible with ALMA gas line observations.
We find that the gas surface density in the "gaps" is reduced by 50% to 80% relative to an unperturbed model. Should embedded planets be responsible for carving the gaps then their masses are at most a few 10 $M_\oplus$. The observed gaps are wider, with shallower flanks, than expected for planet-disk interaction with such low-mass planets. If forming planetary bodies have undergone collapse and are in the "detachted phase" then they may be directly observable with future facilities such as METIS at the E-ELT.

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A grid of one-dimensional low-mass star formation collapse models

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Numerical simulations of star formation are becoming ever more sophisticated, incorporating new physical processes in increasingly realistic set-ups. These models are being compared to the latest observations through state-of-the-art synthetic renderings that trace the different chemical species present in the protostellar systems. The chemical evolution of the interstellar and protostellar matter is very topical, with more and more chemical databases and reaction solvers available online to the community. The current study was developed to provide a database of relatively simple numerical simulations of protostellar collapse as a template library for observations of cores and very young protostars, and for researchers who wish to test their chemical modelling under dynamic astrophysical conditions. It was also designed to identify statistical trends that may appear when running many models of the formation of low-mass stars by varying the initial conditions. A large set of 143 calculations of the gravitational collapse of an isolated sphere of gas with uniform temperature and a Bonnor-Ebert-like density profile was undertaken using a 1D fully implicit Lagrangian radiation hydrodynamics code. The parameter space covered initial masses from 0.2 to 8 $M_\odot$, temperatures of 5-30 K, and radii $3000 \leq R_0 \leq 30,000$ AU. A spread due to differing initial conditions and optical depths, was found in the thermal evolutionary tracks of the runs. Within less than an order of magnitude, all first and second Larson cores had masses and radii essentially independent of the initial conditions. Radial profiles of the gas density, velocity, and temperature were found to vary much more outside of the first core than inside. The time elapsed between the formation of the first and second cores was found to strongly depend on the first core mass accretion rate, and no first core in our grid of models lived for longer than 2000 years before the onset of the second collapse. The end product of a protostellar cloud collapse, the second Larson core, is at birth a canonical object with a mass and radius of about 3 M_J and 8 R_J, independent of its initial conditions. The evolution sequence which brings the gas to stellar densities can, however, proceed in a variety of scenarios, on different timescales or along different isentropes, but each story line can largely be predicted by the initial conditions. All the data from the simulations are publicly available at this address: `http://starformation.hpc.ku.dk/grid-of-protostars`.

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CSI 2264: Investigating rotation and its connection with disk accretion in the young open cluster NGC 2264

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The low spin rates measured for solar-type stars at an age of a few Myr (∼10% of the break-up velocity) indicate that some mechanism of angular momentum regulation must be at play in the early pre-main sequence. We characterize the rotation properties for members of the region NGC 2264 (∼3 Myr), and investigate the accretion-rotation connection at an age where about 50% of the stars have already lost their disks. We examined a sample of 500 cluster members whose photometric variations were monitored in the optical for 38 consecutive days with CoRoT. Light curves were analyzed for periodicity using the Lomb-Scargle periodogram, the autocorrelation function and the string-length method. The period distribution obtained for the cluster consists of a smooth distribution centered around P=5.2 d with two peaks at P=1–2 d and 3–4 d. A separate analysis of CTTS and WTTS indicates that the P=1–2 d peak is associated with the latter, while both groups contribute to the P=3–4 d peak. The comparison between CTTS and WTTS supports the idea of a rotation-accretion connection: their respective rotational properties are statistically different, and CTTS rotate on average more slowly than WTTS. We also observe a clear dearth of fast rotators with strong accretion signatures (large UV flux excess). This is consistent with earlier findings that fast rotators in young star clusters are typically devoid of dusty disks. Our sample shows some evidence of a mass dependence in the rotation properties of NGC 2264 members, lower-mass stars spinning on average faster. This study confirms that disks influence the rotational evolution of young stars. The idea of disk-locking may be consistent with the picture of rotation and rotation-accretion connection that we observe for the NGC 2264 cluster. However, the origin of the several substructures that we observe in the period distribution deserves further investigation.

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http://arxiv.org/pdf/1610.08811

The Mid-Infrared Polarization of the Herbig Ae Star WL 16: An Interstellar Origin?

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We present high-resolution ($0''.4$) mid-infrared (mid-IR) polarimetric images and spectra of WL 16, a Herbig Ae star at a distance of 125 pc. WL 16 is surrounded by a protoplanetary disk of ∼900 AU in diameter, making it one of the most extended Herbig Ae/Be disks as seen in the mid-IR. The star is behind, or embedded in, the ρ Ophiuchus molecular cloud, and obscured by 28 magnitudes of extinction at optical wavelengths by the foreground cloud. Mid-IR polarization of WL 16, mainly arises from aligned elongated dust grains present along the line of sight, suggesting a uniform morphology of polarization vectors with an orientation of 33° (East from North) and a polarization fraction of ∼2.0%. This orientation is consistent with previous polarimetric surveys in the optical and near-IR bands to probe large-scale magnetic fields in the Ophiuchus star formation region, indicating that the observed mid-IR polarization toward WL 16 is produced by the dichroic absorption of magnetically aligned foreground dust grains by a uniform magnetic field. Using polarizations of WL 16 and Elias 29, a nearby polarization standard star, we constrain the polarization efficiency, $p_{10.3}/A_{10.3}$, for the dust grains in the ρ Ophiuchus molecular cloud to be $\sim$1.0% mag^{-1}. WL 16 has polycyclic aromatic hydrocarbon (PAH) emission features detected at 8.6, 11.2, 12.0, and 12.7 μm by our spectroscopic data, and we find an anti-correlation between the PAH surface brightness and the PAH ionization fraction between the NW and SW sides of the disk.

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http://arxiv.org/pdf/1610.07906

Planetesimal clearing and size-dependent asteroid retention by secular resonance sweeping during the depletion of the solar nebula

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The distribution of heavy elements is anomalously low in the asteroid main belt region compared with elsewhere in the solar system. Observational surveys also indicate a deficit in the number of small ($\lesssim$50 km size) asteroids that is two orders of magnitude lower than what is expected from the single power-law distribution that results from a collisional coagulation and fragmentation equilibrium. Here, we consider the possibility that a major fraction of the original asteroid population may have been cleared out by Jupiter's secular resonance, as it swept through the main asteroid belt during the depletion of the solar nebula. This effect leads to the excitation of the asteroids' orbital eccentricities. Concurrently, hydrodynamic drag and planet-disk tidal interaction effectively damp the eccentricities of sub-100 km-size and of super-lunar-size planetesimals, respectively. These combined effects lead to the asteroids' orbital decay and clearing from the present-day main belt region ($\sim$2.1–3.3 AU). The intermediate-size (50 to several hundreds of kilometers) planetesimals therefore preferentially remain as main belt asteroids near their birthplaces, with modest asymptotic eccentricities. The smaller asteroids are the fragments of subsequent disruptive collisions at later times as suggested by the present-day asteroid families. This scenario provides a natural explanation for both the observed low surface density and the size distribution of asteroids in the main belt. It also offers an explanation for the confined spatial extent of the terrestrial planet building blocks without the requirement of extensive migration of Jupiter.

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http://arxiv.org/pdf/1610.09670

Excess C/O and C/H in outer protoplanetary disk gas

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The compositions of nascent planets depend on the compositions of their birth disks. In particular, the elemental compositions of Gas Giant gaseous envelopes depend on the elemental composition of the disk gas from which the envelope is accreted. Previous models demonstrated that sequential freeze-out of O and C-bearing volatiles in disks will result in an supersolar C/O ratios and subsolar C/H ratios in the gas between water and CO snowlines. This result does not take into account, however, the expected grain growth and radial drift of pebbles in disks, and the accompanying re-distribution of volatiles from the outer to the inner disk. Using a toy model we demonstrate that when drift is considered, CO is enhanced between the water and CO snowline, resulting in both supersolar C/O and C/H ratios in the disk gas in the Gas Giant formation zone. This result appears robust to the details of the disk model as long as there is substantial pebble drift across the CO snowline, and the efficiency of CO vapor diffusion is limited. Gas Giants that accrete their gaseous envelopes exterior to the water snowline and do not experience substantial core-envelope mixing, may thus present both superstellar C/O and C/H ratios in their atmospheres. Pebble drift will also affect the nitrogen and noble gas abundances in the planet forming zones, which may explain some of Jupiter's peculiar abundance patterns.

Accepted by ApJL

http://arxiv.org/pdf/1610.07859

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Abstracts of recently accepted major reviews

Accretion onto Pre-Main-Sequence Stars

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Accretion through circumstellar disks plays an important role in star formation and in establishing the properties of the regions in which planets form and migrate. The mechanisms by which protostellar and protoplanetary disks accrete onto low-mass stars are not clear; angular momentum transport by magnetic fields is thought to be involved, but the low-ionization conditions in major regions of protoplanetary disks lead to a variety of complex nonideal magnetohydrodynamic effects whose implications are not fully understood. Accretion in pre-main-sequence stars of masses <1 $M_\odot$ (and in at least some 2–3 $M_\odot$ systems) is generally funneled by the stellar magnetic field, which disrupts the disk at scales typically of order a few stellar radii. Matter moving at near free-fall velocities shocks at the stellar surface; the resulting accretion luminosities from the dissipation of kinetic energy indicate that mass addition during the T Tauri phase over the typical disk lifetime ∼3 Myr is modest in terms of stellar evolution, but is comparable to total disk reservoirs as estimated from millimeter-wave dust emission ($\sim 10^{-2}$ $M_\odot$). Pre-main-sequence accretion is not steady, encompassing timescales ranging from approximately hours to a century, with longer-timescale variations tending to be the largest. Accretion during the protostellar phase – while the protostellar envelope is still falling onto the disk – is much less well understood, mostly because the properties of the central obscured protostar are difficult to estimate. Kinematic measurements of protostellar masses with new interferometric facilities should improve estimates of accretion rates during the earliest phases of star formation.

Accepted by ARAA Review

http://adsabs.harvard.edu/abs/2016ARA%26A..54..135H

Challenges in Planet Formation

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Over the past two decades, large strides have been made in the field of planet formation. Yet fundamental questions remain. Here we review our state of understanding of five fundamental bottlenecks in planet formation. These are: 1) the structure and evolution of protoplanetary disks; 2) the growth of the first planetesimals; 3) orbital migration driven by interactions between proto-planets and gaseous disk; 4) the origin of the Solar System's orbital architecture; and 5) the relationship between observed super-Earths and our own terrestrial planets. Given our lack of understanding of these issues, even the most successful formation models remain on shaky ground.

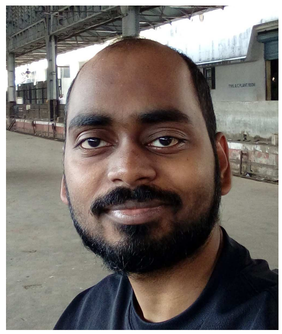
Accepted by JGR-planets

http://arxiv.org/pdf/1610.07202

Dissertation Abstracts

Episodic Accretion and Outflows in Young Stellar Objects & Near Infrared Instrumentation

Joe Philip Ninan



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Ph.D dissertation directed by: Prof. Devendra K. Ojha

Ph.D degree awarded: October 2016

In the first part of this thesis, I present results of our long-term multi-wavelength monitoring of FUors and EXors sources (MFES program), to characterise and understand the eruptive outburst phenomenon seen in young stellar objects (YSOs). We did a detailed analysis of two of the most peculiar sources in the family of young eruptive sources, V899 Mon and V1647 Ori. Both of them showed a mixture of photometric and spectroscopic signatures of classical FUors as well as classical EXors; possibly indicating that the distribution of eruptive young variables form a continuous spectrum, not bimodal. We detected V899 Mon undergoing short term quiescence, and could monitor the simultaneous evolution of the accretion and the outflows. This gave a direct observational evidence of correlation between accretion and outflow. Our analysis of V899 Mon and V1647 Ori showed that the pure disc instability models cannot explain the short period quiescence seen in both of these objects. We proposed support for mechanisms which can temporarily pause magnetospheric accretion, without requiring the disc surface density to drop below a critical value (as required by various instability models). Our detection of heavily fluctuating high velocity outflows in V899 Mon prior to the transition strongly suggests instabilities in the magnetospheric accretion. From our detection of large velocity fluctuations in the outflow from V899 Mon, we could constrain the outflow mechanism, and probably made the first detection of the polar winds driven by the magnetic pressure, similar to the winds in the propeller regime of a rotating magnetosphere. We also present a hierarchical Bayesian model to incorporate all the photometric observations of star-forming regions to estimate these episodic accretion outburst frequency. This model, for the first time, enables us to quantitatively analyse variations in the outburst phenomena across various age clusters of YSOs. In the second part of the thesis, for the study of heavily embedded sources in the MFES program, we also developed a TIFR Near Infrared Imager and Spectrograph Camera (TIRSPEC). After the detailed calibrations and performance analyses, the instrument was released to the public in May 2014, and currently it is heavily used by the astronomy community. Unified pipelines for the data reduction of all the instruments used in the MFES program (optical and near-infrared, imagers and spectrographs) were also written and released to the public under GNU GPL3+ license.

https://indiajoe.gitlab.io/files/PhDThesis_JPNinan.pdf

New Jobs

Postdoctoral Position in Astrochemistry and Star/Planet Formation

The Center for Astrochemical Studies (CAS; http://www.mpe.mpg.de/CAS) at the Max Planck Institute for Extraterrestrial Physics (MPE) in Garching (near Munich), Germany, invites applications for a Postdoctoral position in astrochemistry and observational/theoretical star and planet formation. The overall aim of the project is to study star and planet formation, from the parent clouds to protoplanetary disks, with links to our Solar System, using molecular lines and dust continuum observations as tools to unveil the physical and chemical evolution of gas and dust. This will be done by constraining (magneto-)hydro-dynamical and chemical models with high sensitivity and high angular/spectral resolution observations via the use of radiative transfer codes. Researchers with experience in interstellar dust processing, theory and/or observations of star and planet forming regions are encouraged to apply.

The flexible starting date could be as early as Spring 2017, for 2 years guaranteed with the possibility of extension to up to five years and further career within MPE. Applicants should have a PhD in astronomy or related field before starting. The post comes with a generous travel allowance. Please send a letter of application, a brief description of research interests, a curriculum vitae including bibliography, and three letters of reference by December 15th, 2016 to: Paola Caselli (caselli@mpe.mpg.de).

Later applications may also be considered in case the post is not filled until January 15th 2017. The Max-Planck Society is an equal opportunity employer, yet specifically aims to increase the number of female employees.

Two Postdoc Positions: Complex Organic Molecules in Star Forming Regions

The Reaction Dynamics Group, W.M. Keck Laboratory in Astrochemistry, Department of Chemistry, University of Hawai'i at Manoa, invites applications for two postdoctoral positions in the area of Laboratory Astrophysics (condensed phase). The prime directive is to explore in simulation experiments the formation of complex organic molecules (COMs) in star forming regions via the interaction of ionizing radiation (charged particles; VUV) with ices exploiting a next-generation surface science machine along with reflectron time of flight mass spectrometry coupled with photoionization (ReTOF-PI); structural isomers are identified selectively by utilizing single photon tunable vacuum ultraviolet light generated by four wave mixing processes.

The appointment period is initially for one year, but can be renewed annually based on availability of funds and satisfactory progress. The salary is competitive and commensurate with experience. Successful applicants must have a strong background in one or more of the following areas: four wave mixing schemes, UHV technology, pulsed lasers, labview. Solid communication skills in English (written, oral), a publication record in internationally circulated, peer-reviewed journals, and willingness to work in a team are mandatory Only self-motivated and energetic candidates are encouraged to apply. Please send a letter of interest, three letters of recommendation, CV, and publication list to Prof. Ralf I. Kaiser, Department of Chemistry, University of Hawai'i at Manoa, Honolulu, HI 96822-2275, USA [ralfk@hawaii.edu]. The review of applications will start January 1, 2017, and continues until the positions are filled. A description of our current research group can be found at `http://www.chem.hawaii.edu/Bil301/welcome.html`.

Summary of Upcoming Meetings

Search for life: from early Earth to exoplanets
12 - 16 December 2016, Quy Nhon, Vietnam
http://rencontresduvietnam.org/conferences/2016/search-for-life

Disks, Dynamos, and Data: Confronting MHD Accretion Theory with Observations
6 - 10 February 2017, Santa Barbara, USA
https://www.kitp.ucsb.edu/activities/disks-c17

The Physics of the ISM - 6 years of ISM-SPP 1573: what have we learned?
13 - 17 February 2017, Cologne, Germany
https://hera.ph1.uni-koeln.de/~ism2017/

Star Formation from Cores to Clusters
6 - 9 March 2017, Santiago, Chile
http://www.eso.org/sci/meetings/2017/star-formation2017.html

Astrochemistry VII - Through the Cosmos from Galaxies to Planets
20 - 24 March 2017, Puerto Varas, Chile
http://newt.phys.unsw.edu.au/IAUS332/

Formation and Dynamical Evolution of Exoplanets
26 - 31 March 2017, Aspen, USA
http://ciera.northwestern.edu/Aspen2017.php

Multi-Scale Star Formation
3 - 7 April 2017, Morelia, Mexico
http://www.irya.unam.mx/multi-scaleSF17/

Protoplanetary Disks and Planet Formation and Evolution
29 May - 23 June 2017, Garching bei München, Germany
http://www.munich-iapp.de/scientific-programme/programmes-2017/protoplanetary-disks/

Accretion, Differentiation and Early Evolution of Terrestrial Planets
29 May - 3 June 2017, Nice, France
https://www-n.oca.eu/morby/Accrete.html

Gordon Research Seminar Origins of Solar Systems
17 - 18 June 2017, South Hadley, USA
https://www.grc.org/programs.aspx?id=17506

Gordon Research Conference Origins of Solar Systems: Making a Habitable Planet
18 - 23 June 2017, South Hadley, USA
https://www.grc.org/programs.aspx?id=12346

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

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

Other meetings: http://www1.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/meetings/