The Star Formation Newsletter

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

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Cover Picture

A hydrodynamic simulation of an M dwarf with a massive protostellar disk in which gravitational fragmentation leads to the rapid formation of a protoplanet.


Submitting your abstracts

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifl.hawaii.edu) are appended to each Call for Abstracts. You can also submit via the Newsletter web interface at http://www2.ifl.hawaii.edu/star-formation/index.cfm
Eric Keto
in conversation with Bo Reipurth

Q: What was your thesis about and who was your adviser?
A: My thesis with Paul Ho was titled, "Microwave spectroscopy and Gravitational Collapse". We used the VLA and the NH₃ lines at 23 GHz to map the accretion flow onto a small group of massive stars, G10.6-0.4. The VLA had just recently been completed and for the first time provided arcsecond angular resolution at radio frequencies, similar to the resolution of ground-based optical observations. Spectroscopy provided the information necessary to estimate the structure along the line-of-sight. For example, the gas temperatures from the NH₃ hyperfine line ratios indicate the radial distance from the emission to the central cluster. This was the first mapping of the whirlpool motion of a star-forming accretion flow, although feeding several massive stars simultaneously. The journal article received a recognition from the AAS as a significant result in astronomy in 1987. I remember when I handed the bound copies of my thesis to our department administrator, she said, "This is only 30 pages. Did your advisor read this?" I said, "Don't know, but he signed it."

Q: In 1986 you published a paper with Phil Myers with CO maps of high-latitude clouds.
A: That was my first publication in astronomy and as with my PhD thesis was made possible by new instrumentation. The IRAS satellite had recently discovered wide-spread IR emission from dust in the low-density HI clouds that make up part of the Galactic disk. In some regions, compression within these turbulent clouds creates densities high enough for CO to persist by self-shielding. We used Pat Thaddeus's 1m antenna on Cerro Tololo to observe this CO.

We found that the high-latitude CO clouds are bound by external pressure. This turns out to be the ram pressure of the HI turbulence, a finding made possible by another new advancement, in this case in numerical hydrodynamics. John Lattanzio and I used Joe Monaghan's first version of his smoothed-particle hydrodynamics code to simulate this turbulent compression and reproduce the complex supersonic spectral line shapes seen in CO.

Q: Not long after, you published several papers on the ultracompact HII region G10.6-0.4. What is special about G10.6-0.4?
A: The high-latitude clouds are mostly of interest because of their CO absorption and dust extinction and the effects on other observations.

The first of these publications came out of my PhD thesis. The VLA receivers at that time did not have the sensitivity to observe thermal NH₃ emission at combined sub-arcsecond and kms⁻¹ resolution. So Paul Ho and I used the UCHII region as a back light to observe NH₃ in absorption. The total ionization from the several stars within the common UCHII region creates a particularly bright radio continuum, and their combined mass extends the radius of high infall velocities to a resolvable size. Later I mapped the accretion flow in the ionized gas using radio recombination lines. On top of all that, Paul managed to get two more PhD theses out of G10.6-0.4. There are just a few of these bright, massive, accreting UCHII regions in the Galaxy. This was our first.

Q: In a series of papers you have also dealt with the problem of the formation of massive stars as a competition between gravitational attraction and thermal pressure of the HII region. What are your main findings?
A: The main conclusion is a new understanding of HII regions as part of the accretion process. The textbook model of spherical expansion driven by the pressure difference between the hot gas ionized by the star and the surrounding cold neutral gas neglects the gravitational force necessary for star formation. Although this works well enough for giant optical HII regions that are large enough that the gravitational attraction is negligible at the HII boundary, a better model for accreting stars is described in Mestel's 1954 paper as ionization within a Bondi accretion flow. However, lacking the double-front structure of the HII boundary, ionization plus shock, first described by Savedoff and Greene in the following year, Mestel's model is inconsistent in the subsonic part of the accretion flow. I put the two concepts together in 2003 to describe the full accretion flow from subsonic to supersonic and show that accretion is possible through an HII region with the flow transitioning from molecular to ionized. In a 2007 study of two-dimensional accretion, I found that the density gradient owing to rotational flattening results in accretion along the dense mid-plane, transitioning from molecular to ionized, simultaneously with a pressure-driven ionized outflow along the poles. This model captures the essential features seen in later numerical hydrodynamic simu-
lattions, for example in Peters et al. 2010, and Kuiper et al. 2019. Simultaneous accretion and outflow works well with the observations as seen in Thomas Peters's paper and earlier with Kenny Wood in 2006. So we should really think of HII regions around massive protostars as an active element in the accretion dynamics.

Q: You have worked with Paola Caselli on a division of starless cores into two classes, depending on the central density. What is the main idea?

A: The two classes are sometimes referred to as "starless" and "pre-stellar", although both are starless since neither contain protostars. This division, and the confusing nomenclature, refers to an observational distinction. The "starless" starless cores are more nearly isothermal, less dense, less massive, less chemically depleted and have narrower line widths than the "pre-stellar" starless cores. The latter are presumed to be on the verge of gravitational collapse and star formation. Earlier, Neal Evans pointed out that cores without a protostar should be heated from the outside by the background near-UV of the Galaxy and cooled from the inside by IR emission from dust. George Field and I developed this idea into a more complete model of radiative and chemical equilibrium including cooling by molecular lines and heating by cosmic rays and infall compression. The optical depth at different wavelengths from the UV to millimeter (molecular lines) affects the radiative equilibrium and the chemical abundances. Paola and I found that the observational differences between the two classes can all be explained simply by varying the central density. In hydrostatic equilibrium, the central density is a single parameter describing the overall core density and therefore the optical depth as well. Maybe the title of the paper should have been, "There is really only one class of starless cores."

Q: You have had an interest in the question about oscillations of starless cores. What is the status of that subject?

A: For the moment, finished. This topic began when Charlie Lada pointed out that variations in spectral line profiles across B68 require more complex motions than any combination of rotation and either contraction or expansion. Along with Avery Broderick and Ramesh Narayan, we found that the line profiles are consistent with subsonic turbulence described as a collection of oscillatory modes with wavelengths on the order of the core size. These oscillations are similar to those seen in stars such as the Sun. In contrast with the Sun, the thermal and turbulent energies in the starless cores are comparable, and as shown in a paper with Avery, the turbulence contributes to the hydrostatic balance of the cores. Because the cores have no internal sources of energy to replenish the turbulent energy lost through dissipation and radiation, the more massive "starless" starless cores can evolve to "pre-stellar" over time and then to gravitational collapse and star formation. The least massive cores, those with masses below their thermal Bonnor-Ebert critical mass, may end up completely supported by thermal energy.

Q: In a recent paper with Paola Caselli and Jonathan Rawlings you compared observed spectra of the L1544 core with different models of gravitational collapse. What were your findings?

A: This was our next to last paper in a series on the slow contraction of starless cores leading to star formation. The problem addressed is the observational ambiguity of different inflow solutions. The Shu 1977, Larson-Penston 1969, and Keto and Field 2005 models share a density profile scaling as the inverse radius squared, also shared by the hydrostatic model. Discriminating between models by the density profile alone, for example as revealed by dust observations, isn’t possible. However, the models predict different inflow velocities in the inner and outer regions of the core. Our Herschel observations provided us with a spectral line profile for gas-phase, thermal water emission. The critical density for thermal water emission is about 10^5 cm^-3 while the CO is nearly completely depleted from the gas phase at densities above 10^5. So we know that the two emission lines come only from inner and outer regions of the core, respectively. We found that the model of slow quasi-equilibrium contraction described in Keto and Field 2005 matches both observed lines. The supersonic CO line widths and profiles predicted by the other models are not observed. In our last paper, at least so far, we found this model also matched the profile of a high frequency ammonia line observed by Herschel (Caselli et al. 2017).

Q: You recently retired. What are your current plans?

A: A motivation in my shift from high-mass to low-mass star formation was the opportunity at the time to work with some extraordinary people. I hope I can continue. Some of my co-authors have moved to different topics and responsibilities, but George Field and I just published a paper about a new gravitational instability driven by specific entropy in molecular clouds that has relevance for fragmentation and star formation. With Avi Loeb’s help hosting me at Harvard’s Institute for Theory and Computation, I am finding new people and new topics. We don’t know how our plans or we ourselves will evolve. To pay for college, I worked as a geologist with an oil company in New Mexico on a deep-drilling project measuring gamma-rays from uranium deposits in sandstone. Watching the stars sweep over the southwest desert, the mechanical roar of the diesel drilling rig didn’t suggest that later I would be watching the same stars in the same desert a few miles away, but listening to the weep-weep of cryogenically cooled radio receivers. It’s quieter in the astrophysics theory group. Work with good people. Join them. Learn something. Help out. Everyone can help, and the best people accept help.
Determining accurate distances to star-forming regions is critically important for understanding the star formation process, as distance affects the calculation of many physical properties, including mass, density, physical size, and luminosity. Until very recently, distance estimates to star-forming regions—particularly within the solar neighborhood—suffered from large error bars and were obtained non-homogeneously on a cloud-by-cloud basis. This is evident in the Star Formation Handbook (Reipurth 2008, Star Formation Handbook, vols I and II)—a compilation of the sixty most important star-forming regions within $\approx 2 - 3$ kpc. Distance estimates for clouds in the Handbook were obtained using a diversity of techniques, including kinematic methods, parallax-based methods, and methods based on isochrone-fitting of associated stellar clusters. On average, though, ten years ago, distance uncertainties to the Handbook clouds were on the order of $\approx 30\%$, with some distances uncertain by a factor of two.

In this Perspective article, we briefly discuss three major techniques for determining distances to molecular clouds. Two of these methods—the kinematic distance method and the parallax-based method—have a rich history in the literature, but have benefited from the rise of large-scale VLBI surveys (see Reid et al. 2019; Loinard 2013) over the past ten years. The third technique—based in 3D dust mapping—has only become possible within the last 5 years due to the advent of cheap, publicly available all-sky photometry and new statistical machinery. We discuss the current uncertainties associated with each method, where they are best applied, and key observational results. We conclude by presenting a uniform catalog of accurate distances to Star Formation Handbook clouds using 3D dust mapping, with typical distance uncertainties of only $\approx 5\%$ nearby ($< 1.5$ kpc) and $\approx 10\%$ farther away ($> 1.5$ kpc), a factor of $\approx 5$ improvement over previous estimates available when the Handbook was published.

1 Kinematic Distances

Kinematic distances are determined using a cloud’s radial velocity in combination with an adopted rotation curve for the Galaxy. Assuming that a cloud is in purely circular rotation around the Galactic center, one can connect the radial velocity of the cloud to a unique Galactocentric radius $R$ using a rotation curve. This Galactocentric radius can then be converted to a distance using geometric arguments (see Roman-Duval et al. 2009 and Figure 1). Beyond the solar circle ($R > R_\odot$), the radial velocity of the cloud uniquely identifies its distance. However, inside the solar circle ($R < R_\odot$), a single radial velocity associated with the same Galactocentric radius can correspond to two different distances, known as the “near” and “far” kinematic distances. This distance ambiguity is difficult to resolve, but can be narrowed down using a number of approaches (e.g. HI self-absorption, Galactic latitude of the cloud in question, the size-linewidth relationship, association with masers; see e.g. Rice et al. 2016, Anderson et al. 2012, Roman-Duval et al. 2009), with some approaches much more discriminative than others.

The main benefit of the kinematic distance method is that it is very easy to apply, as long as the cloud’s radial velocity is known and is expected to follow Galactic rotation. Mention of kinematic distances in the Astrophysical Data System (ADS) dates back to the 1960s and 1970s, and are even more readily applied today due to the advent of high-resolution CO and HI surveys (e.g. COHRS, CHIMPS, GRS, FUGIN, GALFA; Dempsey et al. 2013, Rigby et al. 2015, Jackson et al. 2006, Umemoto et al. 2017, Peek et al. 2011). Errors in kinematic distances derive from uncertainties in the Galactic rotation curve, the inability to resolve the kinematic distance ambiguity, and the presence of non-circular “peculiar” motions. While recent BeSSeL results (The Bar And Spiral Structure Legacy Survey; Reid et al. 2019) calibrate the rotation curve to unprecedented accuracy using distances and velocities of high-mass star-forming regions, individual molecular clouds are still heavily affected by peculiar motions. These deviations occur due to feedback (e.g. supernovae) or due to streaming motions near spiral arms and the Galactic bar. The latter means that the kinematic distance method is considered particularly unreliable near the Galactic center ($|l| < 15^\circ$). Recent numerical simulations quantifying the impact of streaming motions on kinematic distance determinations estimate average uncertainties of 1 kpc, though they can be as high as 2 kpc in some regions (Ramon-Fox & Bonnell 2018). Kinematic distances also cannot be reliably used for local clouds with...
small radial velocities (within the nearest $\approx 1$ kpc) since the obtainable distance resolution is coarser than the peculiar motions for objects so close to the Sun.

The kinematic distance method is useful for deriving distances to clouds en masse, so the method is often applied to Galaxy-wide cloud catalogs derived from clever decompositions of CO emission into a set of molecular clouds (e.g. dendrograms, SCIMES; see Rice et al. 2016, Colombo et al. 2018, Miville-Deschenes et al. 2017a). Due to the effects described above, however, typical uncertainties are on the order of $\approx 30\%$, though this can be much larger in certain cases. In the context of the Star Formation Handbook, the kinematic distance method has been used to derive distances to farther away “local” clouds (between 1-3 kpc). For instance, previous kinematic distance estimates for the W3 complex discussed in the Handbook (Megeath et al. 2008) places it around 3.5-4 kpc (Heyer & Terebey 1998) while modern parallax-based methods (from BeSSeL; Reid et al. 2019, see §2) place it at 2 kpc (Reid et al. 2019), likely due to large streaming motions near the Perseus Arm. A similar story occurs for the star-forming region M17, which suffers uncertainty in its kinematic distance due to its longitude of $l = 15^\circ$, near the Galactic center. Previous kinematic distance estimates placed it between 2.0-2.4 kpc (Chini & Hoffmeister 2008), while modern measurements based on Gaia astrometry towards the M17 cluster (Kuhn et al. 2019) and 3D dust mapping (Zucker et al. 2020) place it closer, around 1500-1600 pc.

2 Parallax-Based Distances

Parallax is the apparent angular shift of the position of stars on the plane of the sky, caused by the Earth’s orbit around the Sun. Given that the location of the Earth relative to the Sun is known, the angular shift in the source’s position over time can be related to a distance with trigonometry. Parallax-based approaches offer a more direct measurement of distance compared to kinematic methods, and come with significantly smaller error bars. As such, parallax is considered the “gold standard” of distance determination.

Stellar parallax has traditionally been measured at optical wavelengths, with the first major breakthrough coming in the 1990s with the Hipparcos mission (Perryman et al. 1997). Hipparcos measured the trigonometric parallax of around 100,000 stars (most within the nearest few hundred parsecs) with typical uncertainties of $\approx 1$ mas. The recent release of Gaia (Lindegren et al. 2018) increased the stellar sample by four orders of magnitude, up to 1 billion stars. Gaia achieves a typical uncertainty of 0.04 mas for the brightest stars and 0.7 mas for the very faintest stars. In the Gaia era, parallax-based distances can be determined to molecular clouds by determining distances to young stars and clusters confirmed to be associated with them based on previous X-ray, optical, and infrared studies. For example, Grollschedl et al. 2018 uses a sample of 700 mid-infrared selected young stellar objects with Gaia distances towards the Orion A molecular cloud to construct a 3D map of the region, determining that Orion A is actually a 90 pc long filament, with a significant distance gradient along the line of sight (see also Kounkel at al 2018). Similar work was carried out by Kuhn et al. 2019, which uses a combination of infrared and X-ray surveys to identify a sample of YSOs (ages between 1-5 Myr) with Gaia distances towards around 20 nearby stellar clusters.

While Gaia provides accurate distances to 1 billion stars, it is an optical instrument, and as such cannot probe the densest star-forming regions due to dust extinction. To do so, one needs radio observations, and recent VLBI surveys like the BeSSeL survey (Reid et al. 2014, 2019) and The Gould’s Belt Distances Survey (GOBELINS) (Loinard 2013) channel the strengths of Gaia at much longer wavelengths. At radio wavelengths, there are two types of sources bright enough to be detected with VLBI
Figure 2: Left: Plots of extinction (in mag) as a function of distance (in kpc) for three different sightlines from Neckel & Klare (1980). Each black dot marks the distance and extinction measurement of an individual star. The black line indicates the model for the distribution of dust along the line of sight. Right: Plot of extinction as a function of distance modulus for one sightline from Zucker et al. (2020). Each red cross marks the most probable distance and extinction for individual stars. The blue line indicates the best-fit model for the distribution of dust along the line of sight. The sharp increase in extinction in all panels indicates the existence of a dust cloud at that distance, as the cloud is being bracketed by unextinguished foreground stars and extinguished background stars.

3 3D Dust Mapping Distances

Using stars to trace “dark nebulae” has its roots in the early twentieth century (see Wolf 1923 and his accompanying “Wolf diagrams”) but in the modern era, 3D dust mapping is based on the principle outlined in Neckel & Klare 1980. In short, Neckel & Klare 1980 determine the distance and extinction to stars of known spectral type along different sightlines through nearby molecular clouds. To do so, they needed to know three quantities for each star: its apparent colors, its absolute magnitude, and its (unreddened) intrinsic colors; the former can be derived from photometry while the latter two can be derived from the star’s Morgan-Keenan (MK) spectral type, which uniquely parameterizes a star’s luminosity. Knowing all three allows for the determination of the star’s distance modulus (and thus its distance) as well as the integrated extinction between the observer and the star. Repeating this procedure for many stars in the same region of the sky allows one to build up a model for the dust as a function of distance, because any dust cloud will appear as a “break” in extinction, bracketed between unextinguished foreground stars and extinguished background stars. This is evident in the left panel of Figure 2, which shows extinction as a function of distance for three different sightlines from Neckel & Klare 1980. A sharp rise in extinction coincident with the cloud’s distance is apparent in each panel.

Neckel & Klare 1980 limited their sample to 11,000 stars with known spectral type, so only a few dozen stars were available per region. Even today, however, spectroscopy is only available for millions of stars, while photometry is available for billions. New statistical infrastructure in
combination with high-performance computing now allows for the determination of accurate distances to molecular clouds using only photometry of stars, which is cheaply and publicly available. While a star’s type, distance, and extinction can now be determined using photometry alone (see e.g. Green et al. 2014; Zucker & Speagle et al. 2019), new parallax measurements from Gaia inform stellar distance estimates based on photometry when available, which in turn considerably improves distances to local molecular clouds. The right panel of Figure 2 shows a distance-extinction plot for a sightline through the Vela C molecular cloud, available in the new study by Zucker et al. 2020. Thus, compared to VLBI approaches, 3D dust mapping technique can provide coverage over a much larger sample of local molecular clouds, since it requires neither compact radio emission nor YSOs observable with Gaia in order to constrain distances. Rather, it relies on inferring the distance and extinction to unassociated stars in front of and behind the cloud using optical and near-infrared surveys (from Pan-STARRS1, DECaPS, NSC, and 2MASS; see Chambers et al. 2016, Schlafly et al. 2018, Nidever et al. 2018, Skrutskie et al. 2006). This means that 3D dust mapping is targeting the material around cores, rather than the cores themselves, due
Using this framework, Zucker et al. 2020 produce a uniform catalog of accurate distances to sixty star-forming regions in the Star Formation Handbook – the largest of its kind – with typical uncertainties of 5 – 6% nearby and 10% further away (> 1.5 kpc). A bird’s eye view of the distribution of these clouds is shown in Figure 3. Not only can 3D dust mapping provide coverage across a larger sample of clouds, but it can also reveal the 3D structure within an individual cloud, because much larger areas of each cloud can be targeted. In this vein, detailed distance maps – revealing evidence of distance gradients and/or multiple components – are available for a subset of twenty-five of the most famous molecular clouds in the Star Formation Handbook (see Figure 8 in Zucker & Speagle et al. 2019; tinyurl.com/sfn-fig2). On a cloud-by-cloud basis, comparison of these 3D dust based distances with VLBI-parallax based distances (BeSSeL and GOBELINS; see §2) shows that the dust distances agree with the VLBI distances to < 10% out to 2.5 kpc with no systematic offsets (see Figure 4). For GOBELINS clouds which show evidence of distance gradients, including Perseus (≈ 25 pc gradient; Ortiz-Leon et al. 2018), 3D dust mapping techniques obtain not only the same average distances, but also the same distance gradients (see Zucker et al. 2018).

The main limitation of 3D dust mapping is that unlike VLBI approaches it cannot easily target the most extinguished regions in local molecular clouds (AV > 10 mag) or clouds > 3 kpc away in the Galactic plane. This is because the method relies on seeing stars through clouds to constrain distances, which is difficult particularly in the Galactic plane, when there are multiple clouds along the line of sight. However, new, deeper infrared data (from UKIDSS, VVV, GLIMPSE, and unWISE; Lucas et al. 2007, Alonso-García et al. 2018, Benjamin et al. 2003, Schlafly et al. 2019) should produce significantly more stars visible behind dense regions. These datasets are currently being integrated (Zucker et al. 2020b, in prep) and cloud distance catalogs complete out to ≈ 6 kpc should become available in the coming years.

4 Conclusions

It is an exciting time to map distances to star-forming regions. The rise of high-angular resolution spectral-line surveys, in combination with more precise rotation curves are providing kinematic distances to thousands of clouds across the Galactic disk. The release of Gaia (Lindegren et al. 2018) mapped the position of one billion stars, and the release of VLBI astrometry from GOBELINS and BeSSeL provided accurate distances to star-forming regions with bright compact radio emission in the solar neighborhood and beyond. In the midst of it all, 3D dust mapping is providing accurate distances to regions where kinematic distances are unreliable and that VLBI-based approaches cannot target. This has enabled the creation of a catalog of distances to sixty famous nearby star-forming regions in the Star Formation Handbook, which agrees with VLBI parallax-derived distances to within < 10% in regions of overlap (Zucker et al. 2020). The incorporation of deeper near-infrared data, in combination with enhanced statistical methodology, should allow 3D dust mapping to extend its reach beyond local molecular clouds, towards dust enshrouded regions deep in the Galactic plane.

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2MASS J15491331-3539118: a new low-mass wide companion of the GQ Lup system


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Substellar companions at wide separation around stars hosting planets or brown dwarfs (BDs) yet close enough for their formation in the circumstellar disc are of special interest. In this letter we report the discovery of a wide (projected separation \(\sim 16.0 \text{ arcsec}, \text{or} 2400 \text{ AU}, \text{and position angle} 114.61^\circ\)) companion of the GQ Lup A-B system, most likely gravitationally bound to it. A VLT/X-Shooter spectrum shows that this star, 2MASS J15491331-3539118, is a bonafide low-mass (\(\sim 0.15 \, M_\odot\)) young stellar object (YSO) with stellar and accretion/ejection properties typical of Lupus YSOs of similar mass, and with kinematics consistent with that of the GQ Lup A-B system. A possible scenario for the formation of the triple system is that GQ Lup A and 2MASS J15491331-3539118 formed by fragmentation of a turbulent core in the Lup I filament, while GQ Lup B, the BD companion of GQ Lup A at 0.7 arcsec, formed in situ by the fragmentation of the circumprimary disc. The recent discoveries that stars form along cloud filaments would favour the scenario of turbulent fragmentation for the formation of GQ Lup A and 2MASS J15491331-3539118.

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A Galactic-scale gas wave in the Solar Neighborhood

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For the past 150 years, the prevailing view of the local Interstellar Medium (ISM) was based on a peculiarity known as the Gould’s Belt, an expanding ring of young stars, gas, and dust, tilted about 20° to the Galactic plane. Still, the physical relation between local gas clouds has remained practically unknown because the distance accuracy to clouds is of the same order or larger than their sizes. With the advent of large photometric surveys and the Gaia satellite astrometric survey this situation has changed. Here we report the 3-D structure of all local cloud complexes. We find a narrow and coherent 2.7 kpc arrangement of dense gas in the Solar neighborhood that contains many of the clouds thought to be associated with the Gould Belt. This finding is inconsistent with the notion that these clouds are part
of a ring, disputing the Gould Belt model. The new structure comprises the majority of nearby star-forming regions, has an aspect ratio of about 1:20, and contains about 3 million solar masses of gas. Remarkably, the new structure appears to be undulating and its 3-D distribution is well described by a damped sinusoidal wave on the plane of the Milky Way, with an average period of about 2 kpc and a maximum amplitude of about 160 pc. Our results represent a first step in the revision of the local gas distribution and Galactic structure and offer a new, broader context to studies on the transformation of molecular gas into stars.

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The Gaia-ESO Survey: a new approach to chemically characterising young open clusters
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Open clusters (OCs) are recognised as excellent tracers of Galactic thin-disc properties. At variance with intermediate-age and old OCs, for which a significant number of studies is now available, clusters younger than 150 Myr have been mostly overlooked in terms of their chemical composition, with few exceptions. On the other hand, previous investigations seem to indicate an anomalous behaviour of young clusters, which includes slightly sub-solar iron (Fe) abundances and extreme, unexpectedly high barium (Ba) enhancements. In a series of papers, we plan to expand our understanding of this topic and investigate whether these chemical peculiarities are instead related to abundance analysis techniques. We present a new determination of the atmospheric parameters for 23 dwarf stars observed by the Gaia-ESO survey in five young OCs (younger than 150 Myr) and one star-forming region (NGC 2264). We exploit a new method based on titanium (Ti) lines to derive the spectroscopic surface gravity, and most importantly, the microturbulence parameter. A combination of Ti I and Fe I lines is used to obtain effective temperatures. We also infer the abundances of Fe II, Ti II, Na I, Mg I, Al I, Si I, Ca I, Cr I and Ni I. Our findings are in fair agreement with Gaia-ESO iDR5 results for effective temperatures and surface gravities, but suggest that for very young stars, the microturbulence parameter is over-estimated when Fe lines are employed. This affects the derived chemical composition and causes the metal content of very young clusters to be under-estimated. Our clusters display a metallicity [Fe/H] between +0.04 and +0.12; they are not more metal poor than the Sun. Although based on a relatively small sample size, our explorative study suggests that we may not need to call for ad hoc explanations to reconcile the chemical composition of young OCs with Galactic chemical evolution models.

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Questioning the spatial origin of complex organic molecules in young protostars with the CALYPSO survey
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Context. Complex organic molecules (COMs) have been detected in a few Class 0 protostars but their origin is not well understood. While the usual picture of a hot corino explains their presence as resulting from the heating of the inner envelope by the nascent protostar, shocks in the outflow, a disk wind, the presence of a flared disk, or the interaction region between envelope and disk at the centrifugal barrier have also been claimed to enhance the abundance of COMs. Aims. Going beyond studies of individual objects, we want to investigate the origin of COMs in young protostars on a statistical basis. Methods We use the CALYPSO survey performed with the Plateau de Bure Interferometer of the Institut de Radioastronomie Millimétrique (IRAM) to search for COMs at high angular resolution in a sample of 26 solar-type protostars, including 22 Class 0 and four Class I objects. We derive the column densities of the detected molecules under the local thermodynamic equilibrium approximation and search for correlations between their abundances and with various source properties. Results. Methanol is detected in 12 sources and tentatively in one source, which represents half of the sample. Eight sources (30%) have detections of at least three COMs. We find a strong chemical differentiation in multiple systems with five systems having one component with at least three COMs detected but the other component devoid of COM emission. All sources with a luminosity higher than 4 $L_\odot$ have at least one detected COM whereas no COM emission is detected in sources with internal luminosity lower than 2 $L_\odot$, likely because of a lack of sensitivity. The internal luminosity is found to be the source parameter impacting the most the COM chemical composition of the sources, while there is no obvious correlation between the detection of COM emission and that of a disk-like structure. A canonical hot-corino origin may explain the COM emission in four sources, an accretion-shock origin in two or possibly three sources, and an outflow origin in three sources. The CALYPSO sources with COM detections can be classified into three groups on the basis of the abundances of oxygen-bearing molecules, cyanides, and CHO-bearing molecules. These chemical groups correlate neither with the COM origin scenarios, nor with the evolutionary status of the sources if we take the ratio of envelope mass to internal luminosity as an evolutionary tracer. We find strong correlations between molecules that are a priori not related chemically (for instance methanol and methyl cyanide), implying that the existence of a correlation does not imply a chemical link. Conclusions. The CALYPSO survey has revealed a chemical differentiation in multiple systems that is markedly different from the case of the prototypical binary IRAS16293-2422. This raises the question whether all low-mass protostars go through a phase showing COM emission. A larger sample of young protostars and a more accurate determination of their internal luminosity will be necessary to make further progress. Searching for correlations between the COM emission and the jet/outflow properties of the sources may also be promising.

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$^{13}$C$^{17}$O suggests gravitational instability in the HL Tau disc
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We present the first detection of the $^{13}$C$^{17}$O J=3–2 transition toward the HL Tau protoplanetary disc. We find significantly more gas mass (at least a factor of ten higher) than has been previously reported using $^{18}$O emission. This brings the observed total disc mass to 0.2 $M_\odot$, which we consider to be a conservative lower limit. Our analysis of the Toomre Q profile suggests that this brings the disc into the regime of gravitational instability. The radial region of instability (50–110 au) coincides with the location of a proposed planet-carved gap in the dust disc and a spiral in the gas. We, therefore, propose that if the origin of the gap is confirmed to be due to a forming giant planet, then it is likely to have formed via the gravitational fragmentation of the protoplanetary disc.

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Fragmentation favoured in discs around higher mass stars
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We investigate how a protoplanetary disc’s susceptibility to gravitational instabilities and fragmentation depends on the mass of its host star. We use 1D disc models in conjunction with 3D SPH simulations to determine the critical disc-to-star mass ratios at which discs become unstable against fragmentation, finding that discs become increasingly prone to the effects of self-gravity as we increase the host star mass. The actual limit for stability is sensitive to the disc temperature, so if the disc is optically thin stellar irradiation can dramatically stabilise discs against gravitational instability. However, even when this is the case we find that discs around $2M_\odot$ stars are prone to fragmentation, which will act to produce wide-orbit giant planets and brown dwarfs. The consequences of this work are two-fold: that low mass stars could in principle support high disc-to-star mass ratios, and that higher mass stars have discs that are more prone to fragmentation, which is qualitatively consistent with observations that favour high-mass wide-orbit planets around higher mass stars. We also find that the initial masses of these planets depends on the temperature in the disc at large radii, which itself depends on the level of stellar irradiation.

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ALMA reveals a large structured disk and nested rotating outflows in DG Tau B

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We present Atacama Large Millimeter Array (ALMA) Band 6 observations at 14-20 au spatial resolution of the disk and CO(2-1) outflow around the Class I protostar DG Tau B in Taurus. The disk is very large, both in dust continuum ($R_{\text{eff,95\%}}=174$ au) and CO ($R_{\text{CO}}=700$ au). It shows Keplerian rotation around a $1.1\pm0.2M_\odot$ central star and two dust emission bumps at $r=62$ and 135 au. These results confirm that large structured disks can form at an early stage where residual infall is still ongoing. The redshifted CO outflow at high velocity shows a striking hollow cone morphology out to 3000 au with a shear-like velocity structure within the cone walls. These walls coincide with the scattered light cavity, and they appear to be rooted within $<60$ au in the disk. We confirm their global average rotation in the same sense as the disk, with a specific angular momentum $\approx 65$ au km s$^{-1}$. The mass-flux rate of $1.7-2.9 \times 10^{-7}M_\odot$ yr$^{-1}$ is 35-10 times that in the atomic jet. We also detect a wider and slower outflow component surrounding this inner conical flow, which also rotates in the same direction as the disk. Our ALMA observations therefore demonstrate that the inner cone walls, and the associated scattered light cavity, do not trace the interface with infalling material, which is shown to be confined to much wider angles ($>70^\circ$). The properties of the conical walls are suggestive of the interaction between an episodic inner jet or wind with an outer disk wind, or of a massive disk wind originating from 2-5 au. However, further modeling is required to establish their origin. In either case, such massive outflow may significantly affect the disk structure and evolution.

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Pebble drift and planetesimal formation in protoplanetary discs with embedded planets

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Nearly-axisymmetric gaps and rings are commonly observed in protoplanetary discs. The leading theory regarding
the origin of these patterns is that they are due to dust trapping at the edges of gas gaps induced by the gravitational torques from embedded planets. If the concentration of solids at the gap edges becomes high enough, it could potentially result in planetesimal formation by the streaming instability. We test this hypothesis by performing global 1-D simulations of dust evolution and planetesimal formation in a protoplanetary disc that is perturbed by multiple planets. We explore different combinations of particle sizes, disc parameters, and planetary masses, and find that planetesimals form in all these cases. We also compare the spatial distribution of pebbles from our simulations with protoplanetary disc observations. Planets larger than one pebble isolation mass catch drifting pebbles efficiently at the edge of their gas gaps, and depending on the efficiency of planetesimal formation at the gap edges, the protoplanetary disc transforms within a few 100,000 years to either a transition disc with a large inner hole devoid of dust or to a disc with narrow bright rings. For simulations with planetary masses lower than the pebble isolation mass, the outcome is a disc with a series of weak ring patterns but no strong depletion between the rings. Lowering the pebble size artificially to 100 micrometer-sized “silt”, we find that regions between planets get depleted of their pebble mass on a longer time-scale of up to 0.5 million years. These simulations also produce fewer planetesimals than in the nominal model with millimeter-sized particles and always have at least two rings of pebbles still visible after 1 Myr.

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A survey for variable young stars with small telescopes: II – Mapping a protoplanetary disk with stable structures at 0.15 AU

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The HOYS citizen science project conducts long term, multifilter, high cadence monitoring of large YSO samples with a wide variety of professional and amateur telescopes. We present the analysis of the light curve of V1490 Cyg in the Pelican Nebula. We show that colour terms in the diverse photometric data can be calibrated out to achieve a median photometric accuracy of 0.02 mag in broadband filters, allowing detailed investigations into a variety of variability amplitudes over timescales from hours to several years. Using GaiaDR2 we estimate the distance to the Pelican Nebula to be 870±70 pc. V1490 Cyg is a quasi-periodic dipper with a period of 31.447±0.011d. The obscuring dust has homogeneous properties, and grains larger than those typical in the ISM. Larger variability on short timescales is observed in U and $\text{R}_{\alpha}$ – $\text{H}_{\alpha}$, with U-amplitudes reaching 3 mag on timescales of hours, indicating the source is accreting. The H$\alpha$ equivalent width and NIR/MIR colours place V1490 Cyg between CTTS/WTTS and transition disk objects. The material responsible for the dipping is located in a warped inner disk, about 0.15 au from the star. This mass reservoir can be filled and emptied on time scales shorter than the period at a rate of up to $10^{-10} M_{\odot}$ yr$^{-1}$, consistent with low levels of accretion in other T Tauri stars. Most likely the warp at this separation from the star is induced by a protoplanet in the inner accretion disk. However, we cannot fully rule out the possibility of an AA Tau-like warp, or occultations by the Hill sphere around a forming planet.

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First Resolved Dust Continuum Measurements of Individual Giant Molecular Clouds in the Andromeda Galaxy

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In our local Galactic neighborhood, molecular clouds are best studied using a combination of dust measurements,
to determine robust masses, sizes and internal structures of the clouds, and molecular-line observations to determine cloud kinematics and chemistry. We present here the first results of a program designed to extend such studies to nearby galaxies beyond the Magellanic Clouds. Utilizing the wideband upgrade of the Submillimeter Array (SMA) at 230 GHz we have obtained the first continuum detections of the thermal dust emission on sub-GMC scales (∼ 15 pc) within the Andromeda galaxy (M 31). These include the first resolved continuum detections of dust emission from individual GMCs beyond the Magellanic Clouds. Utilizing a powerful capability of the SMA, we simultaneously recorded CO(2-1) emission with identical (u, v) coverage, astrometry and calibration, enabling the first measurements of the CO conversion factor, \( \alpha_{\text{CO(2-1)}} \), toward individual GMCs across an external galaxy. Our direct measurement yields an average CO–to–dust mass conversion factor of \( \alpha'_{\text{CO-dust}} = 0.042 \pm 0.018 \) M\(_\odot\) (K km s\(^{-1}\) pc\(^{-2}\))\(^{-1}\) for the \( J = 2 \rightarrow 1 \) transition. This value does not appear to vary with galactocentric radius. Assuming a constant gas-to-dust ratio of 136, the resulting \( \alpha_{\text{CO}} = 5.7 \pm 2.4 \) M\(_\odot\) (K km s\(^{-1}\) pc\(^{-2}\))\(^{-1}\) for the 2-1 transition, is in excellent agreement with that of Milky Way GMCs, given the uncertainties. Finally, using the same analysis techniques, we compare our results with observations of the local Orion molecular clouds, placed at the distance of M 31 and simulated to appear as they would if observed by the SMA.

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Corona-Australis DANCe. I. Revisiting the census of stars with Gaia-DR2 data

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Context: Corona-Australis is one of the nearest regions to the Sun with recent and ongoing star formation, but the current picture of its stellar (and substellar) content is not complete yet.

Aims: We take advantage of the second data release of the Gaia space mission to revisit the stellar census and search for additional members of the young stellar association in Corona-Australis.

Methods: We applied a probabilistic method to infer membership probabilities based on a multidimensional astrometric and photometric data set over a field of 128 deg\(^2\) around the dark clouds of the region.

Results: We identify 313 high-probability candidate members to the Corona-Australis association, 262 of which had never been reported as members before. Our sample of members covers the magnitude range between \( G > 5 \) mag and \( G < 20 \) mag, and it reveals the existence of two kinematically and spatially distinct subgroups. There is a distributed ‘off-cloud’ population of stars located in the north of the dark clouds that is twice as numerous as the historically known ‘on-cloud’ population that is concentrated around the densest cores. By comparing the location of the stars in the HR-diagram with evolutionary models, we show that these two populations are younger than 10 Myr. Based on their infrared excess emission, we identify 28 Class II and 215 Class III stars among the sources with available infrared photometry, and we conclude that the frequency of Class II stars (i.e. ‘disc-bearing’ stars) in the on-cloud region is twice as large as compared to the off-cloud population. The distance derived for the Corona-Australis region based on this updated census is \( d = 149.4^{+0.4}_{-0.4} \) pc, which exceeds previous estimates by about 20 pc.

Conclusions: In this paper we provide the most complete census of stars in Corona-Australis available to date that can be confirmed with Gaia data. Furthermore, we report on the discovery of an extended and more evolved population of young stars beyond the region of the dark clouds, which was extensively surveyed in the past.

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Angular momentum profiles of Class 0 protostellar envelopes  
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Understanding the initial properties of star forming material and how they affect the star formation process is a key question. The infalling gas must redistribute most of its initial angular momentum inherited from prestellar cores before reaching the central stellar embryo. Disk formation has been naturally considered as a possible solution to this "angular momentum problem". However, how the initial angular momentum of protostellar cores is distributed and evolves during the main accretion phase and the beginning of disk formation has largely remained unconstrained up to now. In the framework of the IRAM CALYPSO survey, we obtained observations of the dense gas kinematics that we used to quantify the amount and distribution of specific angular momentum at all scales in collapsing-rotating Class 0 protostellar envelopes. We used the high dynamic range C\textsuperscript{18}O (2–1) and N\textsubscript{2}H\textsuperscript{+} (1–0) datasets to produce centroid velocity maps and probe the rotational motions in the sample of 12 envelopes from scales ~50 to ~5000 au. We identify differential rotation motions at scales <1600 au in 11 out of the 12 protostellar envelopes of our sample by measuring the velocity gradient along the equatorial axis, which we fit with a power-law model \( v \propto r^{\alpha} \). This suggests that coherent motions dominate the kinematics in the inner protostellar envelopes. The radial distributions of specific angular momentum in the CALYPSO sample suggest the following two distinct regimes within protostellar envelopes: the specific angular momentum decreases as \( j \propto r^{-0.2} \) down to ~1600 au and then tends to become relatively constant around \( \sim 6 \times 10^{-4} \) km s\textsuperscript{-1} pc down to ~50 au. The values of specific angular momentum measured in the inner Class 0 envelopes suggest that material directly involved in the star formation process (<1600 au) has a specific angular momentum on the same order of magnitude as what is inferred in small T-Tauri disks. Thus, disk formation appears to be a direct consequence of angular momentum conservation during the collapse. Our analysis reveals a dispersion of the directions of velocity gradients at envelope scales >1600 au, suggesting that these gradients may not be directly related to rotational motions of the envelopes. We conclude that the specific angular momentum observed at these scales could find its origin in other mechanisms, such as core-forming motions (infall, turbulence), or trace an imprint of the initial conditions for the formation of protostellar cores.  
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What determines the formation and characteristics of protoplanetary discs?  
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Planets form in protoplanetary discs. Their masses, distribution, and orbits sensitively depend on the structure of the protoplanetary discs. However, what sets the initial structure of the discs in terms of mass, radius and accretion rate is still unknown. We perform non-ideal MHD numerical simulations using the adaptive mesh refinement code Ramses, of a collapsing, one solar mass, molecular core to study the disc formation and early, up to 100 kyr, evolution, paying great attention to the impact of numerical resolution and accretion scheme. We found that while the mass of the
central object is almost independent of the numerical parameters such as the resolution and the accretion scheme onto the sink particle, the disc mass, and to a lower extent its size, heavily depend on the accretion scheme, which we found, is itself resolution dependent. This implies that the accretion onto the star and through the disc are largely decoupled. For a relatively large domain of initial conditions (except at low magnetisation), we found that the properties of the disc do not change too significantly. In particular both the level of initial rotation and turbulence do not influence the disc properties provide the core is sufficiently magnetized. After a short relaxation phase, the disc settles in a stationary state. It then slowly grows in size but not in mass. The disc itself is weakly magnetized but its immediate surrounding is on the contrary highly magnetized. Our results show that the disc properties directly depend on the inner boundary condition, i.e. the accretion scheme onto the central object, suggesting that the disc mass is eventually controlled by the small scale accretion process, possibly the star-disc interaction. Because of ambipolar diffusion and its significant resistivity, the disc diversity remains limited and except for low magnetisation, their properties are weakly sensitive to initial conditions such as rotation and turbulence.

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Survival of Primordial Planetary Atmospheres: Photodissociation Driven Mass Loss
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The most widely-studied mechanism of mass loss from extrasolar planets is photoevaporation via XUV ionization, primarily in the context of highly irradiated planets. However, the lower energy regime of FUV dissociation of hydrogen molecules can also theoretically drive atmospheric evaporation on low-mass planets because the dissociation energy of hydrogen is an order of magnitude greater than the escape energy per proton from the gravity well of an Earth-sized planet. For temperate planets such as the early Earth, impact erosion is expected to dominate in the traditional planetesimal accretion model, but it would be greatly reduced in pebble accretion scenarios, allowing other mass loss processes to be major contributors. We apply the same prescription for photoionization to this photodissociation mechanism and compare it to an analysis of other possible sources of mass loss in pebble accretion scenarios. We find that energy-limited photodissociation could remove the hydrogen atmosphere of an early Earth analog over several Gyr, though not over the shorter period of mass loss in Earth’s early history. Impact erosion could remove ~2,300 bars of hydrogen if 1% of the planet’s mass is accreted as planetesimals, and these are dominant over all other mass loss processes. Similar results apply to super-Earths and mini-Neptunes, which have only modestly greater escape energies. This mechanism could also preferentially remove hydrogen from a planet’s primordial atmosphere, thereby leaving a larger abundance of primordial water compared to standard dry formation models. We discuss the implications of these results for models of rocky planet formation including Earth’s formation and the possible application of this analysis to mass loss from observed exoplanets.

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A multi-frequency ALMA characterization of substructures in the GM Aur protoplanetary disk
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The protoplanetary disk around the T Tauri star GM Aur was one of the first hypothesized to be in the midst of being cleared out by a forming planet. As a result, GM Aur has had an outsized influence on our understanding of disk structure and evolution. We present 1.1 and 2.1 mm ALMA continuum observations of the GM Aur disk at a resolution...
of ∼50 mas (∼8 au), as well as HCO+ J=3–2 observations at a resolution of ∼100 mas. The dust continuum shows at least three rings atop faint, extended emission. Unresolved emission is detected at the center of the disk cavity at both wavelengths, likely due to a combination of dust and free-free emission. Compared to the 1.1 mm image, the 2.1 mm image shows a more pronounced “shoulder” near R ∼ 40 au, highlighting the utility of longer-wavelength observations for characterizing disk substructures. The spectral index α features strong radial variations, with minima near the emission peaks and maxima near the gaps. While low spectral indices have often been ascribed to grain growth and dust trapping, the optical depth of GM Aur’s inner two emission rings renders their dust properties ambiguous. The gaps and outer disk (R > 100 au) are optically thin at both wavelengths. Meanwhile, the HCO+ emission indicates that the gas cavity is more compact than the dust cavity traced by the millimeter continuum, similar to other disks traditionally classified as “transitional.”

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The Evolutionary Status of Protostellar Clumps Hosting Class II Methanol Masers
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The Methanol MultiBeam survey (MMB) provides the most complete sample of Galactic massive young stellar objects (MYSOs) hosting 6.7 GHz class II methanol masers. We characterise the properties of these maser sources using dust emission detected by the Herschel Infrared Galactic Plane Survey (Hi-GAL) to assess their evolutionary state. Associating 731 (73%) of MMB sources with compact emission at four Hi-GAL wavelengths, we derive clump properties and define the requirements of a MYSO to host a 6.7 GHz maser. The median far-infrared (FIR) mass and luminosity are 630 M⊙ and 2500 L⊙ for sources on the near side of Galactic centre and 3200 M⊙ and 10000 L⊙ for more distant sources. The median luminosity-to-mass ratio is similar for both at ∼4.2 L⊙ M⊙−1. We identify an apparent minimum 70 µm luminosity required to sustain a methanol maser of a given luminosity (with L70 ≈ L6.70.6). The maser host clumps have higher mass and higher FIR luminosities than the general Galactic population of protostellar MYSOs. Using principal component analysis, we find 896 protostellar clumps satisfy the requirements to host a methanol maser but lack a detection in the MMB. Finding a 70 µm flux density deficiency in these objects, we favour the scenario in which these objects are evolved beyond the age where a luminous 6.7 GHz maser can be sustained. Finally, segregation by association with secondary maser species identifies evolutionary differences within the population of 6.7 GHz sources.

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Spiral arms and instability within the AFGL 4176 mm1 disc
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We present high-resolution (30 mas or 130 au at 4.2 kpc) Atacama Large Millimeter/submillimeter Array observations
at 1.2 mm of the disc around the forming O-type star AFGL 4176 mm1. The disc (AFGL 4176 mm1-main) has a radius of \( \sim 1000 \) au and contains significant structure, most notably a spiral arm on its redshifted side. We fitted the observed spiral with logarithmic and Archimedean spiral models. We find that both models can describe its structure, but the Archimedean spiral with a varying pitch angle fits its morphology marginally better. As well as signatures of rotation across the disc, we observe gas arcs in CH\(_3\)CN that connect to other millimetre continuum sources in the field, supporting the picture of interactions within a small cluster around AFGL 4176 mm1-main. Using local thermodynamic equilibrium modelling of the CH\(_3\)CN K-ladder, we determine the temperature and velocity field across the disc, and thus produce a map of the Toomre stability parameter. Our results indicate that the outer disc is gravitationally unstable and has already fragmented or is likely to fragment in the future, possibly producing further companions. These observations provide evidence that disc fragmentation is one possible pathway towards explaining the high fraction of multiple systems around high-mass stars.

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Photometric, kinematic and variability study in the young open cluster NGC 1960

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We present a comprehensive photometric analysis of a young open cluster NGC 1960 (M36) along with the long-term variability study of this cluster. Based on the kinematic data of Gaia DR2, the membership probabilities of 3871 stars are ascertained in the cluster field among which 262 stars are found to be cluster members. Considering the kinematic and trigonometric measurements of the cluster members, we estimate a mean cluster parallax of 0.86\(\pm\)0.05 mas and mean proper motions of \(\mu_{RA} = -0.143 \pm 0.008 \) mas yr\(^{-1}\), \(\mu_{Dec} = -3.395 \pm 0.008 \) mas yr\(^{-1}\). We obtain basic parameters of the cluster such as \(E(B-V) = 0.24 \pm 0.02\) mag, \(\log(Age/yr) = 7.44 \pm 0.02\), and distance = 1.17\(\pm\)0.06 kpc. The mass function slope in the cluster for the stars in the mass range of 0.72–7.32 \(M_\odot\) is found to be \(\gamma = -1.26 \pm 0.19\). We find that mass segregation is still taking place in the cluster which is yet to be dynamically relaxed. This work also presents first high-precision variability survey in the central 13\('\)\(\times\)13\('\) among which 72 are periodic variables. Among them, 59 are short-period (\(P < 1\) day) and 13 are long-period (\(P > 1\) day). The variable stars have \(V\) magnitudes ranging between 9.1 to 19.4 mag and periods between 41 minutes to 10.74 days. On the basis of their locations in the H-R diagram, periods and characteristic light curves, the 20 periodic variables belong to the cluster. We classified them as 2 \(\delta\)-Scuti, 3 \(\gamma\)-Dor, 2 slowly pulsating B stars, 5 rotational variables, 2 non-pulsating B stars and 6 as miscellaneous variables.

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Distortion of Magnetic Fields in Barnard 335

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In this study, the detailed magnetic field structure of the dense protostellar core Barnard 335 (B335) was revealed based on near-infrared polarimetric observations of background stars to measure dichroically polarized light produced by magnetically aligned dust grains in the core. Magnetic fields pervading B335 were mapped using 24 stars after subtracting unrelated ambient polarization components, for the first time revealing that they have an axisymmetrically distorted hourglass-shaped structure toward the protostellar core. On the basis of simple two- and three-dimensional magnetic field modeling, magnetic inclination angles in the plane-of-sky and line-of-sight directions were determined to be $90\pm7^\circ$ and $50\pm10^\circ$, respectively. The total magnetic field strength of B335 was determined to be $30.2\pm17.7 \mu G$. The critical mass of B335, evaluated using both magnetic and thermal/turbulent support against collapse, was determined to be $M_{\text{cr}} = 3.37 \pm 0.94 M_\odot$, which is identical to the observed core mass of $M_{\text{core}} = 3.67 M_\odot$. We thus concluded that B335 started its contraction from a condition near equilibrium. We found a linear relationship in the polarization versus extinction diagram, up to $A_V \sim 15$ mag toward the stars with the greatest obscuration, which verified that our observations and analysis provide an accurate depiction of the core.

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Detection of Irregular, Sub-mm Opaque Structures in the Orion Molecular Clouds: Protopstars within 10000 years of formation?

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We report ALMA and VLA continuum observations that potentially identify the four youngest protostars in the Orion Molecular Clouds taken as part of the Orion VANDAM program. These are distinguished by bright, extended, irregular emission at 0.87 and 8 mm and are optically thick at 0.87 mm. These structures are distinct from the disk or point-like morphologies seen toward the other Orion protostars. The 0.87 mm emission implies temperatures of 41-170 K, requiring internal heating. The bright 8 mm emission implies masses of 0.5 to 1.2 Msun assuming standard dust opacity models. One source has a Class 0 companion, while another exhibits substructure indicating a companion-candidate. Three compact outflows are detected, two of which may be driven by companions, with dynamical times of 7300 to ?1400 years. The slowest outflow may be driven by a first hydrostatic core. These protostars appear to trace an early phase when the centers of collapsing fragments become optically thick to their own radiation and compression raises the gas temperature. This phase is thought to accompany the formation of hydrostatic cores. A key question is whether these structures are evolving on free fall times of ?100 years, or whether they are evolving on Kelvin-Helmholtz times of several thousand years. The number of these sources imply a lifetime of ?6000 years, in closer agreement with the Kelvin-Helmholtz time. In this case, rotational and/or magnetic support could be slowing the collapse.

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A Turbulent-Entropic Instability and the Fragmentation of Star-Forming Clouds
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The kinetic energy of supersonic turbulence within interstellar clouds is subject to cooling by dissipation in shocks and subsequent line radiation. The clouds are therefore susceptible to a condensation process controlled by the specific entropy. In a form analogous to the thermodynamic entropy, the entropy for supersonic turbulence is proportional to the log of the product of the mean turbulent velocity and the size scale. We derive a dispersion relation for the growth of entropic instabilities in a spherical self-gravitating cloud and find that there is a critical maximum dissipation time scale, about equal to the crossing time, that allows for fragmentation and subsequent star formation. However, the time scale for the loss of turbulent energy may be shorter or longer, for example with rapid thermal cooling or the injection of mechanical energy. Differences in the time scale for energy loss in different star-forming regions may result in differences in the outcome, for example, in the initial mass function.

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X-Ray Ionization of Planet-Opened Gaps in Protostellar Disks
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Young planets with masses approaching Jupiter’s have tides strong enough to clear gaps around their orbits in the protostellar disk. Gas flow through the gaps regulates the planets’ further growth and governs the disks’ evolution. Magnetic forces may drive that flow if the gas is sufficiently ionized to couple to the fields. We compute the ionizing effects of the X-rays from the central young star, using Monte Carlo radiative transfer calculations to find the spectrum of Compton-scattered photons reaching the planet’s vicinity. The scattered X-rays ionize the gas at rates similar to or greater than the interstellar cosmic ray rate near planets the mass of Saturn and of Jupiter, located at 5 au and at 10 au, in disks with the interstellar mass fraction of sub-micron dust and with the dust depleted a factor 100. Solving a gas-grain recombination reaction network yields charged particle populations whose ability to carry currents is sufficient to partly couple the magnetic fields to the gas around the planet. Most cases can undergo Hall shear instability, and some can launch magneto-centrifugal winds. However the material on the planet’s orbit has diffusivities so large in all the cases we examine, that magneto-rotational turbulence is prevented and the non-ideal terms govern the magnetic field’s evolution. Thus the flow of gas in the gaps opened by the young giant planets depends crucially on the finite conductivity.

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FOREST Unbiased Galactic plane Imaging survey with the Nobeyama 45 m telescope (FUGIN). VI. Dense gas and mini-starbursts in the W43 giant molecular cloud complex
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We performed new large-scale $^{12}$CO, $^{13}$CO, and C$^{18}$O $J = 1$–0 observations of the W43 giant molecular cloud complex in the tangential direction of the Scutum arm ($l \sim 30^\circ$) as a part of the FUGIN project. The low-density gas traced by $^{12}$CO is distributed over $150 \times 100$ pc ($l \times b$), and has a large velocity dispersion (20–30 km s$^{-1}$). However, the dense gas traced by C$^{18}$O is localized in the W43 Main, G30.5, and W43 South (G29.96-0.02) high-mass star-forming regions in the W43 GMC complex, which have clumpy structures. We found at least two clouds with a velocity difference of $\sim 10$–20 km s$^{-1}$, both of which are likely to be physically associated with these high-mass star-forming regions based on the results of high $^{13}$CO $J = 3$–2 to $J = 1$–0 intensity ratio and morphological correspondence with the infrared dust emission. The velocity separation of these clouds in W43 Main, G30.5, and W43 South is too large for each cloud to be gravitationally bound. We also revealed that the dense gas in the W43 GMC has a high local column density, while "the current SFE" of entire the GMC is low ($\sim 4\%$) compared with the W51 and M17 GMC. We argue that the supersonic cloud-cloud collision hypothesis can explain the origin of the local mini-starbursts and dense gas formation in the W43 GMC complex.

Dispersal of protoplanetary disks by the combination of magnetically driven and photoevaporative winds

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We investigate the roles of magnetically driven disk wind (MDW) and thermally driven photoevaporative wind (PEW) in the long-time evolution of protoplanetary disks. We start simulations from the early phase in which the disk mass is 0.118 $M_\odot$ around a 1 $M_\odot$ star and track the evolution until the disk is completely dispersed. We incorporate the mass loss by PEW and the mass loss and magnetic braking (wind torque) by MDW, in addition to the viscous accretion, viscous heating, and stellar irradiation. We find that MDW and PEW respectively have different roles: magnetically driven wind ejects materials from an inner disk in the early phase, whereas photoevaporation has a dominant role in the late phase in the outer ($\gtrsim 1$au) disk. The disk lifetime, which depends on the combination of MDW, PEW, and viscous accretion, shows a large variation of $\sim 1$–20Myr; the gas is dispersed mainly by the MDW and the PEW in the cases with a low viscosity and the lifetime is sensitive to the mass-loss rate and torque of the MDW, whereas the lifetime is insensitive to these parameters when the viscosity is high. Even in disks with very weak turbulence, the cooperation of MDW and PEW enables the disk dispersal within a few Myr.

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The Herschel view of the dense core population in the Ophiuchus molecular cloud

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Context. Herschel observations of nearby clouds in the Gould Belt support a paradigm for low-mass star formation, starting with the generation of molecular filaments, followed by filament fragmentation, and the concentration of mass into self-gravitating prestellar cores. In the case of the Ophiuchus molecular complex, a rich star formation activity has been documented for many years inside the clumps of L1688, the main and densest cloud of the complex, and in the more quiescent twin cloud L1689 thanks to extensive surveys at infrared and other wavelengths.

Aims. With the unique far-infrared and submillimeter continuum imaging capabilities of the Herschel Space observatory, the closely ($d = 139$ pc) Ophiuchus cloud was extensively mapped at five wavelengths from 70 μm to 500 μm with the aim of providing a complete census of dense cores in this region, including unbound starless cores, bound prestellar cores, and protostellar cores.

Methods. Taking full advantage of the high dynamic range and multi-wavelength nature of the Herschel data, we used the multi-scale decomposition algorithms getfilaments and getsources to identify an essentially complete sample of dense cores and filaments in the cloud and study their properties.

Results. The densest clouds of the Ophiuchus complex, L1688 and L1689, which thus far are only indirectly described as filamentary regions owing to the spatial distribution of their young stellar objects (YSOs), are now confirmed to be dominated by filamentary structures. The tight correlation observed between prestellar cores and filamentary structures in L1688 and L1689 supports the view that solar-type star formation occurs primarily in dense filaments. While the sub clouds of the complex show some disparities, L1689 being apparently less efficient than L1688 at forming stars when considering their total mass budgets, both sub clouds share almost the same prestellar core formation efficiency in dense molecular gas. We also find evidence in the Herschel data for a remarkable concentric geometrical configuration in L1688 which is dominated by up to three arc-like compression fronts and presumably created by shockwave events emanating from the Sco OB2 association, including the neighboring massive (O9V) star σ Sco.

Conclusions. Our Herschel study of the well-documented Ophiuchus region has allowed us to further analyze the influence of several early-type (OB) stars surrounding the complex, thus providing positive feedback and enhancing star formation activity in the dense central part of the region, L1688.

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Physical and chemical modeling of a starless core: L1512

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The deuterium fractionation in starless cores gives us a clue to estimate their lifetime scales, thus allowing us to distinguish between different dynamical theories of core formation. Cores also seem to be subject to a differential N\textsubscript{2} and CO depletion which was not expected from models. We aim to make a survey of 10 cores to estimate their lifetime scales and depletion profiles in detail. After L183, in Serpens, we present the second cloud of the series, L1512 in Auriga. To constrain the lifetime scale, we perform chemical modeling of the deuterium profiles across L1512 based on dust extinction measurements from near-infrared observations and non-local thermal equilibrium radiative transfer with multiple line observations of N\textsubscript{2}H\textsuperscript{+}, N\textsubscript{2}D\textsuperscript{+}, DCO\textsuperscript{+}, CH\textsubscript{3}O, and CO, plus H\textsubscript{2}D\textsuperscript{+} (1\textsubscript{0}−1\textsubscript{1}). We find a peak density of 1.1×10\textsuperscript{5} cm\textsuperscript{-3} and a central temperature of 7.5±1 K, which are respectively higher and lower compared with previous dust emission studies. The depletion factors of N\textsubscript{2}H\textsuperscript{+} and N\textsubscript{2}D\textsuperscript{+} are 27\textsuperscript{±7.5} and 47\textsuperscript{±2} in L1512, intermediate between the two other more advanced and denser starless core cases, L183 and L1544. These factors also indicate a similar freeze-out of N\textsubscript{2} in L1512, compared to the two others despite a peak density one to two orders of magnitude lower. Retrieving CO and N\textsubscript{2} abundance profiles with the chemical model, we find that CO has a depletion factor of ∼430–870 and the N\textsubscript{2} profile is similar to that of CO unlike towards L183. Therefore, L1512 has probably been living long enough so that N\textsubscript{2} chemistry has reached steady state. N\textsubscript{2}H\textsuperscript{+} modeling remains compulsory to assess the precise physical conditions in the center of cold starless cores, rather than dust emission. L1512 is presumably older than 1.4 Myr. Therefore, the dominating core formation mechanism should be ambipolar diffusion for this source.

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VVV-WIT-01: highly obscured classical nova or protostellar collision?

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A search of the first Data Release of the VISTA Variables in the Via Lactea (VVV) Survey discovered the exceptionally red transient VVV-WIT-01 (H − K\textsubscript{s} = 5.2). It peaked before March 2010, then faded by ∼9.5 mag over the following two years. The 1.6–22 μm spectral energy distribution in March 2010 was well fit by a highly obscured black body
with $T \sim 1000 \, K$ and $A_K \sim 6.6 \, \text{mag}$. The source is projected against the Infrared Dark Cloud (IRDC) SDC G331.062−0.294. The chance projection probability is small for any single event ($p \approx 0.01$ to 0.02) which suggests a physical association, e.g. a collision between low mass protostars. However, black body emission at $T \sim 1000 \, K$ is common in classical novae (especially CO novae) at the infrared peak in the light curve, due to condensation of dust $\sim$30–60 days after the explosion. Radio follow up with the Australia Telescope Compact Array (ATCA) detected a fading continuum source with properties consistent with a classical nova but probably inconsistent with colliding protostars. Considering all VVV transients that could have been projected against a cataloged IRDC raises the probability of a chance association to $p = 0.13$ to 0.24. After weighing several options, it appears likely that VVV-WIT-01 was a classical nova event located behind an IRDC.

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The ALMA-PILS survey: Inventory of complex organic molecules towards IRAS 16293−2422 A


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Complex organic molecules (COM) are detected in many sources in the warm inner regions of envelopes surrounding deeply embedded protostars. Exactly how these COM form remains an open question. This study aims to constrain the formation of complex organic molecules through comparisons of their abundances towards the Class 0 protostellar binary IRAS 16293−2422 (IRAS16293). We utilised observations from the ALMA Protostellar Interferometric Line Survey of IRAS16293. The species identification and the rotational temperature and column density estimation were derived by fitting the extracted spectra towards IRAS16293 A and IRAS16293 B with synthetic spectra. The majority of the work in this paper pertains to the analysis of IRAS16293 A for a comparison with the results from the other binary component, which have already been published. We detect 15 different COM, as well as 16 isotopologues towards the most luminous companion protostar IRAS16293 A. Tentative detections of an additional 11 isotopologues are reported. We also searched for and report on the first detections of CH$_3$OCH$_2$OH and t-C$_2$H$_5$OCH$_3$ towards IRAS16293 B and the follow-up detection of CH$_2$CHO and CH$_3$CDO. Twenty-four lines of CHD$_2$OH are also identified. The comparison between the two protostars of the binary system shows significant differences in abundance for some of the species, which are partially correlated to their spatial distribution. The spatial distribution is consistent with the sublimation temperature of the species; those with higher expected sublimation temperatures are located in the most compact region of the hot corino towards IRAS16293 A. This spatial differentiation is not resolved in IRAS16293 B and will require observations at a higher angular resolution. In parallel, the list of identified CHD$_2$OH lines shows the need of accurate spectroscopic data including their line strength.

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Searching for kinematic evidence of Keplerian disks around Class 0 protostars with CALYPSO

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The formation of protoplanetary disks is not well understood. To understand how and when these disks are formed, it is crucial to characterize the kinematics of the youngest protostars at a high angular resolution. Here we study a sample of 16 Class 0 protostars to measure their rotation profile at scales from 50 to 500 au and search for Keplerian rotation. We used high-angular-resolution line observations obtained with the Plateau de Bure Interferometer as part of the CALYPSO large program. From $^{13}$CO ($J = 2 - 1$), $^{18}$O ($J = 2 - 1$) and SO ($N_J = 5_6 - 4_5$) moment maps, we find that seven sources show rotation about the jet axis at a few hundred au scales: SerpS-MM18, L1448-C, L1448-NB, L1527, NGC1333-IRAS2A, NGC1333-IRAS4B, and SVS13-B. We analyzed the kinematics of these sources in the $uv$ plane to derive the rotation profiles down to 50 au scales. We find evidence for Keplerian rotation in only two sources, L1527 and L1448-C. Overall, this suggests that Keplerian disks larger than 50 au are uncommon around Class 0 protostars. However, in some of the sources, the line emission could be optically thick and dominated by the envelope emission. Due to the optical thickness of these envelopes, some of the disks could have remained undetected in our observations.

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A model for the onset of self-gravitation and star formation in molecular gas governed by galactic forces: II. the bottleneck to collapse set by cloud-environment decoupling

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In Meidt et al. (2018), we showed that gas kinematics on the scale of individual molecular clouds are not dominated by self-gravity but also track a component that originates with orbital motion in the potential of the host galaxy. This agrees with observed cloud line widths, which show systematic variations from virial motions with environment, pointing at the influence of the galaxy potential. In this paper, we hypothesize that these motions act to slow down the collapse of gas and so help regulate star formation. Extending the results of Meidt et al. (2018), we derive a dynamical collapse timescale that approaches the free-fall time only once the gas has fully decoupled from the galactic potential. Using this timescale we make predictions for how the fraction of free-falling, strongly self-gravitating gas varies throughout the disks of star-forming galaxies. We also use this collapse timescale to predict variations in the molecular gas star formation efficiency, which is lowered from a maximum, feedback-regulated level in the presence of strong coupling to the galactic potential. Our model implies that gas can only decouple from the galaxy to collapse and efficiently form stars deep within clouds. We show that this naturally explains the observed drop in star formation rate per unit gas mass in the Milky Way’s CMZ and other galaxy centers. The model for a galactic bottleneck to star formation also agrees well with resolved observations of dense gas and star formation in galaxy disks and the properties of local clouds.

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Planet formation around M dwarfs via disc instability

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Context: Around 30 per cent of the observed exoplanets that orbit M dwarf stars are gas giants that are more massive than Jupiter. These planets are prime candidates for formation by disc instability.

Aims: We want to determine the conditions for disc fragmentation around M dwarfs and the properties of the planets that are formed by disc instability.

Methods: We performed hydrodynamic simulations of M dwarf protostellar discs in order to determine the minimum disc mass required for gravitational fragmentation to occur. Different stellar masses, disc radii, and metallicities were considered. The mass of each protostellar disc was steadily increased until the disc fragmented and a protoplanet was formed.

Results: We find that a disc-to-star mass ratio between $\sim 0.3$ and $\sim 0.6$ is required for fragmentation to happen. The minimum mass at which a disc fragments increases with the stellar mass and the disc size. Metallicity does not significantly affect the minimum disc fragmentation mass but high metallicity may suppress fragmentation. Protoplanets form quickly (within a few thousand years) at distances around $\sim 50$ AU from the host star, and they are initially very hot; their centres have temperatures similar to the ones expected at the accretion shocks around planets formed by core accretion (up to 12,000 K). The final properties of these planets (e.g. mass and orbital radius) are determined through long-term disc-planet or planet-planet interactions.

Conclusions: Disc instability is a plausible way to form gas giant planets around M dwarfs provided that discs have at least 30% the mass of their host stars during the initial stages of their formation. Future observations of massive M dwarf discs or planets around very young M dwarfs are required to establish the importance of disc instability for planet formation around low-mass stars.

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A new hybrid radiative transfer method for massive star formation

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Frequency-dependent/hybrid approaches for stellar irradiation are of primary importance in numerical simulations of massive star formation. We seek to compare outflow and accretion mechanisms in star formation simulations. We investigate the accuracy of a hybrid radiative transfer method using the gray M1 closure relation for proto-stellar irradiation and gray flux-limited diffusion (FLD) for photons emitted everywhere else. We have coupled the FLD module of the adaptive-mesh refinement code Ramses with Ramses-RT, which is based on the M1 closure relation. Our hybrid (M1+FLD) method takes an average opacity at the stellar temperature for the M1 module, instead of the local environmental radiation field. We have tested this approach in radiative transfer tests of disks irradiated by a star for three levels of optical thickness and compared the temperature structure with RADMC-3D and MCFOST. We applied it to a radiation-hydrodynamical simulation of massive star formation. Our tests validate our hybrid approach for determining the temperature structure of an irradiated disk in the optically-thin and moderately optically-thick regimes and the most optically-thick test shows the limitation of our approach. The optically-thick setups highlight the ability of the hybrid method to partially capture the self-shielding in the disk while the FLD cannot. The radiative acceleration is 100 times greater with the hybrid method. It consistently leads to about +50% more extended and wider-angle radiative outflows in the massive star formation simulation. We obtain a 17.6 $M_\odot$ at $t \approx 0.7 \tau_{r_{mff}}$, while the accretion phase is ongoing. Finally, despite the use of refinement to resolve the radiative cavities, no Rayleigh-Taylor instability appears in our simulations, and we justify their absence by physical arguments based on the entropy gradient.

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APEX observations of ortho-H$_2$D$^+$ towards dense cores in the Orion B9 filament

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**Context.** Initial conditions and very early stages of star formation can be probed through spectroscopic observations of deuterated molecular species.

**Aims.** We aim to determine the ortho-H$_2$D$^+$ properties (e.g. column density and fractional abundance with respect to H$_2$) in a sample of dense cores in the Orion B9 star-forming filament, and to compare those with the previously determined source characteristics, in particular with the gas kinetic temperature, [N$_2$D$^+$/[N$_2$H$^+$] deuterium fractionation, and level of CO depletion.

**Methods.** We used the Atacama Pathfinder EXperiment (APEX) telescope to observe the 372 GHz ortho-H$_2$D$^+$($J_{K_aK_c} = 1_1,0 - 1_1,1$) line towards three prestellar cores and three protostellar cores in Orion B9. We also employed our previous APEX observations of C$^{17}$O, C$^{18}$O, N$_2$H$^+$, and N$_2$D$^+$ line emission, and 870 µm dust continuum emission towards the target sources.

**Results.** The ortho-H$_2$D$^+$($1_1,0?1_1,1$) line was detected in all three prestellar cores, but in only one of the protostellar cores. The corresponding ortho-H$_2$D$^+$ abundances were derived to be $\sim (12 - 30) \times 10^{-11}$ and $\sim 6 \times 10^{-11}$. Two additional spectral lines, DCO$^+$($5 - 4$) and N$_2$H$^+$($4 - 3$), were detected in the observed frequency bands with high detection rates of 100% and 83%, respectively. We did not find any significant correlations among the explored parameters, although our results are mostly consistent with theoretical expectations. Also, the Orion B9 cores were found to be consistent with the relationship between the ortho-H$_2$D$^+$ abundance and gas temperature obeyed by other low-mass dense cores. The ortho-H$_2$D$^+$ abundance was found to decrease as the core evolves.

**Conclusions.** The ortho-H$_2$D$^+$ abundances in the Orion B9 cores are in line with those found in other low-mass dense cores and larger than derived for high-mass star-forming regions. The higher ortho-H$_2$D$^+$ abundance in prestellar cores compared to that in cores hosting protostars is to be expected from chemical reactions where higher concentrations of gas-phase CO and elevated gas temperature accelerate the destruction of H$_2$D$^+$. The validity of using the ortho-H$_2$D$^+$/[N$_2$D$^+$] abundance ratio as an evolutionary indicator, which has been proposed for massive clumps, remains to be determined when applied to these target cores. Similarly, the behaviour of the ortho-H$_2$D$^+$/[DCO$^+$] ratio as the source evolves was found to be ambiguous. Still larger samples and observations of additional deuterated species are needed to explore these potential evolutionary indicators further. The low radial velocity of the line emission from one of the targeted prestellar cores, SMM 7 ($\sim 3.6$ km s$^{-1}$ versus the systemic Orion B9 velocity of $\sim 9$ km s$^{-1}$), suggests that it is a chance superposition seen towards Orion B9. Overall, as located in a dynamic environment of the Orion B molecular cloud, the Orion B9 filament provides an interesting target system to investigate the deuterium-based chemistry, and further observations of species like para-H$_2$D$^+$ and D$_2$H$^+$ would be of particular interest.

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COBrAs: The e-MERLIN 21 cm Legacy survey of Cygnus OB2


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The role of massive stars is central to an understanding of galactic ecology. It is important to establish the details of how massive stars provide radiative, chemical, and mechanical feedback in galaxies. Central to these issues is an understanding of the evolution of massive stars, and the critical role of mass loss via strongly structured winds and stellar binarity. Ultimately, massive stellar clusters shape the structure and energetics of galaxies. We aim to conduct high-resolution, deep field mapping at 21 cm of the core of the massive Cygnus OB2 association and to characterise the properties of the massive stars and colliding winds at this waveband. We used seven stations of the e-MERLIN radio facility, with its upgraded bandwidth and enhanced sensitivity to conduct a 21 cm census of Cygnus OB2. Based
on 42 hours of observations, seven overlapping pointings were employed over multiple epochs during 2014 resulting in 1σ sensitivities down to \(\sim 21 \mu \text{Jy}\) and a resolution of \(\sim 180 \text{ mas}\). A total of 61 sources are detected at 21cm over a \(\sim 0.48^\circ \times 0.48^\circ\) region centred on the heart of the Cyg OB2 association. Of these 61 sources, 33 are detected for the first time. We detect a number of previously identified sources including four massive stellar binary systems, two YSOs, and several known X-ray and radio sources. We also detect the LBV candidate (possible binary system) and blue hypergiant (BHG) star of Cyg OB2 #12. The 21cm observations secured in the COBRA\$ Legacy project provide data to constrain conditions in the outer wind regions of massive stars; determine the non-thermal properties of massive interacting binaries; examine evidence for transient sources, including those associated with young stellar objects; and provide unidentified sources that merit follow-up observations. The 21cm data are of lasting value and will serve in combination with other key surveys of Cyg OB2.

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Nine localised deviations from Keplerian rotation in the DSHARP circumstellar disks: Kinematic evidence for protoplanets carving the gaps

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We present evidence for localised deviations from Keplerian rotation, i.e., velocity “kinks”, in 8 of 18 circumstellar disks observed by the DSHARP program: DoAr 25, Elias 2-27, GW Lup, HD 143006, HD 163296, IM Lup, Sz 129 and WaOph 6. Most of the kinks are detected over a small range in both radial extent and velocity, suggesting a planetary origin, but for some of them foreground contamination prevents us from measuring their spatial and velocity extent. Because of the DSHARP limited spectral resolution and signal-to-noise in the \(^{12}\text{CO} J=2–1\) line, as well as cloud contamination, the kinks are usually detected in only one spectral channel, and will require confirmation. The strongest circumstantial evidence for protoplanets in the absence of higher spectral resolution data and additional tracers is that, upon deprojection, we find that all of the candidate planets lie within a gap and/or at the end of a spiral detected in dust continuum emission. This suggests that a significant fraction of the dust gaps and spirals observed by ALMA in disks are caused by embedded protoplanets.

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\(M_{\text{dust}}–M_\star\) Relation Hints at the Origin of Particle Traps in Protoplanetary Disks

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Demographic surveys of protoplanetary disks, mainly with ALMA, have provided access to a large range of disk dust masses \((M_{\text{dust}})\) around stars with different stellar types and for different star-forming regions. These surveys found a linear relation in logarithmic scale between \(M_{\text{dust}}\) and \(M_\star\) that steepens with time, but that is flatter for transition disks (TDs). We perform dust evolution models and include perturbations to the gas surface density with different amplitudes to investigate the effect of particle trapping on the \(M_{\text{dust}}–M_\star\) relation. These perturbations aim to mimic pressure bumps originated by planets. We focus on the effect caused by different stellar and disk masses because exoplanet statistics show a dependence of planet mass with stellar mass and metallicity. We find that models of dust evolution can reproduced the observed \(M_{\text{dust}}–M_\star\) relation in different star-forming regions when strong pressure bumps are included and when the disk mass scales with stellar mass (case of \(M_{\text{dust}} = 0.05 M_\star\) in our models). This result arises from dust trapping and dust growth beyond centimeter-size grains inside pressure bumps. However, the flatter relation of \(M_{\text{dust}}–M_\star\) for TDs and disks with substructures cannot be reproduced by the models, unless the
formation of boulders is inhibited inside pressure bumps. In the context of planets originating pressure bumps, our results agree with the current exoplanet statistics about giant planet occurrence increasing with stellar mass, but we cannot conclude about the type of planets needed in the case of low mass stars. This is because for $M_\star < 1 M_\odot$, the observed $M_{\text{dust}}$ obtained from models is very low due to the efficient growth of dust particles beyond centimeter sizes (boulders) inside pressure bumps.

Effect of feedback of massive stars in the fragmentation, distribution, and kinematics of the gas in two star forming regions in the Carina Nebula

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We present ALMA high spatial resolution observations towards two star forming regions located in one of the most extreme zones of star formation in the Galaxy, the Carina Nebula. One region is located at the center of the nebula and is severely affected by the stellar feedback from high-mass stars, while the other region is located further south and is less disturbed by the massive star clusters. We found that the region at the center of the nebula is forming less but more massive cores than the region located in the south, suggesting that the level of stellar feedback effectively influence the fragmentation process in clumps. Lines such as HCN, HCO$^+$ and SiO show abundant and complex gas distributions in both regions, confirming the presence of ionization and shock fronts. Jeans analysis suggests that the observed core masses in the region less affected by the massive stars are consistent with thermal fragmentation, but turbulent Jeans fragmentation might explain the high masses of the cores identified in the region in the center of Carina. Consistently, two different analyses in the HCO$^+$ line provided evidence for a higher level of turbulence in the gas more affected by the stellar feedback. The gas column density probability functions, N-PDFs, show log-normal shapes with clear transitions to power law regimes. We observed a wider N-PDF in the region at the center of the nebula, which provides further evidence for a higher level of turbulence in the material with a higher level of massive stellar feedback.

Detectability of embedded protoplanets from hydrodynamical simulations

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We predict magnitudes for young planets embedded in transit ion discs, still affected by extinction due to material in the disc. We focus on Jupiter-size planets at a late stage of their formation, when the planet has carved a deep gap in the gas and dust distributions and the disc starts being transparent to the planet flux in the infrared (IR). Column densities are estimated by means of three-dimensional hydrodynamical models, performed for several planet masses. Expected magnitudes are obtained by using typical extinction properties of the disc material and evolutionary models of giant planets. For the simulated cases located at 5.2 AU in a disc with local unperturbed surface density of 127
A 1 \text{M}_\odot \text{ planet is highly extincted in } J-, H- \text{ and } K- \text{ bands, with predicted absolute magnitudes } \geq 50 \text{ mag. In } L- \text{ and } M- \text{ bands extinction decreases, with planet magnitudes between 25 and 35 mag. In the } N- \text{ band, due to the silicate feature on the dust opacities, the expected magnitude increases to 40 mag. For a } 2 \text{ M}_\odot \text{ planet, the magnitudes in } J-, H- \text{ and } K- \text{ bands are above } 22 \text{ mag, while for } L-, M- \text{ and } N- \text{ bands the planet magnitudes are between 15 and } 20 \text{ mag. For the } 5 \text{ M}_\odot \text{ planet, extinction does not play a role in any IR band, due to its ability to open deep gaps. Contrast curves are derived for the transition discs in CQ Tau, PDS70, HL Tau, TW Hya and HD163296. Planet mass upper-limits are estimated for the known gaps in the last two systems. Accepted by MNRAS}


SILCC-Zoom: \text{H}_2 - \text{CO-dark gas in molecular clouds - the impact of feedback and magnetic fields}

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We analyse the CO-dark molecular gas content of simulated molecular clouds from the SILCC-Zoom project. The simulations reach a resolution of 0.1 pc and include \text{H}_2 and CO formation, radiative stellar feedback and magnetic fields. CO-dark gas is found in regions with local visual extinctions $A_{V:3D} \sim 0.2 - 1.5$, number densities of $10 - 10^3 \text{ cm}^{-3}$ and gas temperatures below 10 K - 100 K. CO-bright gas is found at number densities above 300 cm$^{-3}$ and temperatures below 50 K. The CO-dark gas fractions range from 40% to 95% and scale inversely with the amount of well-shielded gas ($A_{V:3D} > 1.5$), which is smaller in magnetised molecular clouds. We show that the density, chemical abundances and $A_{V:3D}$ along a given line-of-sight cannot be properly determined from projected quantities. As an example, pixels with a projected visual extinction of $A_{V:2D} \sim 2.5 - 5$ can be both, CO-bright or CO-dark, which can be attributed to the presence or absence of strong density enhancements along the line-of-sight. By producing synthetic CO(1-0) emission maps of the simulations with RADMC-3D, we show that about 15 - 65% of the \text{H}_2 is in regions with intensities below the detection limit. Our clouds have $X_{\text{CO}}$-factors around $1.5 \times 10^{20} \text{ cm}^{-2} (\text{K km s}^{-1})^{-1}$ with a spread of up to a factor $\approx 4$, implying a similar uncertainty in the derived total \text{H}_2 masses and even worse for individual pixels. Based on our results, we suggest a new approach to determine the \text{H}_2 mass, which relies on the availability of CO(1-0) emission and $A_{V:2D}$ maps. It reduces the uncertainty of the clouds' overall \text{H}_2 mass to a factor of $< 1.8$ and for individual pixels, i.e. on sub-pc scales, to a factor of $< 3$.

Accepted by MNRAS


Variable stars in the Sh 2-170 HII region

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We present multi-epoch deep ($\sim 20 \text{ mag}$) $I_c$ band photometric monitoring of the Sh 2-170 star-forming region to understand the variability properties of pre-main-sequence (PMS) stars. We report identification of 47 periodic and 24 non-periodic variable stars with periods and amplitudes ranging from $\sim 4 \text{ hrs}$ to 18 days and from $\sim 0.1$ to 2.0 mag, respectively. We have further classified 49 variables as PMS stars (17 Class II and 32 Class III) and 17 as main-sequence (MS)/field star variables. A larger fraction of MS/field variables (88%) show periodic variability as compared to the PMS variables (59%). The ages and masses of the PMS variable stars are found to be comparable with those of T-Tauri stars. Their variability amplitudes show an increasing trend with the near-IR/mid-IR excess. The period distribution of the PMS variables shows two peaks, one near $\sim 1.5 \text{ days}$ and the other near $\sim 4.5 \text{ days}$. It is found that the younger stars with thicker discs and envelopes seem to rotate slower than their older counterparts. These
properties of the PMS variables support the disc-locking mechanism. Both the period and amplitude of PMS stars show decrease with increasing mass probably due to the effective dispersal of circumstellar discs in massive stars. Our results favour the notion that cool spots on weak line T-Tauri stars are responsible for most of their variations, while hot spots on classical T-Tauri stars resulting from variable mass accretion from an inner disc contribute to their larger amplitudes and irregular behaviours.

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CO-Line and Radio Continuum Study of Elephant Trunks: The Pillars of Creation in M16

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Molecular-line and radio continuum properties of the elephant trunks (ET, pillars of creation) in M16 are investigated by analyzing the $^{12}$CO ($J=1-0$), $^{13}$CO ($J=1-0$) and C$^{18}$O ($J=1-0$)-line survey data with the Nobeyama 45-m telescope and the Galactic plane radio survey at 20 and 90 cm with the Very Large Array. The head clump of Pillar West I is found to be the brightest radio source in M16, showing thermal spectrum and property of a compact HII region with the nearest O5 star in NGC 6611 being the heating source. The radio pillars have cometary structure concave to the molecular trunk head, and the surface brightness distribution obeys a simple illumination law by a remote excitation source. The molecular density in the pillar head is estimated to be several $10^4$ H$_2$ cm$^{-3}$ and molecular mass $\sim$13–40 $M_\odot$. CO-line kinematics reveals random rotation of the clumps in the pillar tail at $\sim$1–2 km s$^{-1}$, comparable to the velocity dispersion and estimated Alfvén velocity. It is suggested that the random directions of velocity gradients would manifest a torsional magnetic oscillation of the clumps around the pillar axis.

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The VLA/ALMA Nascent Disk and Multiplicity (VANDAM) Survey of Orion Protostars. A Statistical Characterization of Class 0 and I Protostellar Disks

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We have conducted a survey of 328 protostars in the Orion molecular clouds with ALMA at 0.87 mm at a resolution of $\sim$0.′1 (40 au), including observations with the VLA at 9 mm toward 148 protostars at a resolution of $\sim$0.′08 (32 au). This is the largest multi-wavelength survey of protostars at this resolution by an order of magnitude. We use the dust continuum emission at 0.87 mm and 9 mm to measure the dust disk radii and masses toward the Class 0, Class I, and Flat Spectrum protostars, characterizing the evolution of these disk properties in the protostellar phase. The mean dust disk radii for the Class 0, Class I, and Flat Spectrum protostars are 44.9$^{+5.8}_{-3.5}$, 37.0$^{+4.9}_{-3.0}$, and 28.5$^{+3.7}_{-2.3}$ au, respectively, and the mean protostellar dust disk masses are 25.9$^{+5.2}_{-3.0}$, 14.9$^{+3.8}_{-2.2}$, 11.6$^{+3.5}_{-1.9}$ Earth masses, respectively. The decrease in dust disk masses is expected from disk evolution and accretion, but the decrease in disk radii may point to the initial conditions of star formation not leading to the systematic growth of disk radii or that radial drift is keeping the dust disk sizes small. At least 146 protostellar disks (35% out of 379 detected 0.87 mm continuum sources plus 42 non-detections) have disk radii greater than 50 au in our sample. These properties are not found to vary significantly between different regions within Orion. The protostellar dust disk mass distributions are systematically larger than that of Class II disks by a factor of $>$4, providing evidence that the cores of giant planets may need to at
least begin their formation during the protostellar phase.

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An Eclipsing Substellar Binary in a Young Triple System discovered by SPECULOOS
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Mass, radius, and age are three of the most fundamental parameters for celestial objects, enabling studies of the evolution and internal physics of stars, brown dwarfs, and planets. Brown dwarfs are hydrogen-rich objects that are unable to sustain core fusion reactions but are supported from collapse by electron degeneracy pressure. As they age, brown dwarfs cool, reducing their radius and luminosity. Young exoplanets follow a similar behaviour. Brown dwarf evolutionary models are relied upon to infer the masses, radii and ages of these objects. Similar models are used to infer the mass and radius of directly imaged exoplanets. Unfortunately, only sparse empirical mass, radius and age measurements are currently available, and the models remain mostly unvalidated. Double-line eclipsing binaries provide the most direct route for the absolute determination of the masses and radii of stars. Here, we report the SPECULOOS discovery of 2M1510A, a nearby, eclipsing, double-line brown dwarf binary, with a widely-separated tertiary brown dwarf companion. We also find that the system is a member of the 45±5 Myr-old moving group, Argus. The system’s age matches those of currently known directly-imaged exoplanets. 2M1510A provides an opportunity to benchmark evolutionary models of brown dwarfs and young planets. We find that widely-used evolutionary models do reproduce the mass, radius and age of the binary components remarkably well, but overestimate the luminosity by up to 0.65 magnitudes, which could result in underestimated photometric masses for directly-imaged exoplanets and young field brown dwarfs by 20 to 35%.

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Constraining planet formation around 6 M⊙–8 M⊙ stars
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Identifying planets around O-type and B-type stars is inherently difficult; the most massive known planet host has a mass of only about 3 M⊙. However, planetary systems which survive the transformation of their host stars into white dwarfs can be detected via photospheric trace metals, circumstellar dusty and gaseous discs, and transits of planetary debris crossing our line-of-sight. These signatures offer the potential to explore the efficiency of planet formation for host stars with masses up to the core-collapse boundary at ≈8 M⊙, a mass regime rarely investigated in planet formation theory. Here, we establish limits on where both major and minor planets must reside around ≈6 M⊙–8 M⊙ stars in order to survive into the white dwarf phase. For this mass range, we find that intact terrestrial or giant planets need to leave the main sequence beyond approximate minimum star-planet separations of respectively about 3 and 6 au. In these systems, rubble pile minor planets of radii 10, 1.0, and 0.1 km would have been shorn apart by giant branch radiative YORP spin-up if they formed and remained within, respectively, tens, hundreds and thousands of au. These boundary values would help distinguish the nature of the progenitor of metal-pollution in white dwarf atmospheres. We find that planet formation around the highest mass white dwarf progenitors may be feasible, and
hence encourage both dedicated planet formation investigations for these systems and spectroscopic analyses of the highest mass white dwarfs.

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The origin of tail-like structures around protoplanetary disks

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We study the origin of tail-like structures recently detected around the disk of SU Aurigae and several FU Orionis-type stars.

Dynamic protostellar disks featuring ejections of gaseous clumps and quiescent protoplanetary disks experiencing a close encounter with an intruder star were modeled using the numerical hydrodynamics code FEOSAD. Both the gas and dust dynamics were taken into account, including dust growth and mutual friction between the gas and dust components. Only plane-of-the-disk encounters were considered.

Ejected clumps produce a unique type of tail that is characterized by a bow-shock shape. Such tails originate from the supersonic motion of ejected clumps through the dense envelope that often surrounds young gravitationally unstable protostellar disks. The ejected clumps either sit at the head of the tail-like structure or disperse if their mass is insufficient to withstand the head wind of the envelope. On the other hand, close encounters with quiescent protoplanetary disks produce three types of the tail-like structure; we define these as pre-collisional, post-collisional, and spiral tails. These tails can in principle be distinguished from one another by particular features of the gas and dust flow in and around them. We find that the brown-dwarf-mass intruders do not capture circumintruder disks during the encounter, while the subsolar-mass intruders can acquire appreciable circumintruder disks with elevated dust-to-gas ratios, which can ease their observational detection. However, this is true only for prograde collisions; the retrograde intruders fail to collect appreciable amounts of gas or dust from the disk of the target. The mass of gas in the tail varies in the range 0.85–11.8 $M_{\text{Jup}}$, while the total mass of dust lies in the 1.75–30.1 $M_{\oplus}$ range, with the spiral tails featuring the highest masses. The predicted mass of dust in the model tail-like structures is therefore higher than what was inferred for similar structures in SU Aur, FU Ori, and Z CMa, making their observational detection feasible.

Tail-like structures around protostellar and protoplanetary disks can be used to infer interesting phenomena such as clump ejection or close encounters. In particular, the bow-shock morphology of the tails could point to clump ejections as a possible formation mechanism. Further numerical and observational studies are needed to better understand the detectability and properties of the tails.

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The HI/OH/Recombination line survey of the inner Milky Way (THOR): data release 2 and HI overview

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The Galactic plane has been observed extensively by a large number of Galactic plane surveys from infrared to radio wavelengths at an angular resolution below 40 arcsec. However, a 21 cm line and continuum survey with comparable spatial resolution is lacking.

The first half of THOR data ($l = 14.0^\circ - 37.9^\circ$, and $l = 47.1^\circ - 51.2^\circ$, $|b| \leq 1.25^\circ$) has been published in our data release 1 paper. With this data release 2 paper, we publish all the remaining spectral line data and Stokes I continuum data with high angular resolution (10 arcsec–40 arcsec), including a new HI dataset for the whole THOR survey region ($l = 14.0 - 67.4^\circ$ and $|b| \leq 1.25^\circ$). As we published the results of OH lines and continuum emission elsewhere, we concentrate on the HI analysis in this paper.

With the Karl G. Jansky Very Large Array (VLA) in C-configuration, we observed a large portion of the first Galactic quadrant, achieving an angular resolution of $\leq 40$ arcsec. At $L$ Band, the WIDAR correlator at the VLA was set to cover the 21 cm HI line, four OH transitions, a series of H$n$$_\alpha$ radio recombination lines (RRLs; $n = 151$ to 186), and eight 128 MHz-wide continuum spectral windows (SPWs), simultaneously.

We publish all OH and RRL data from the C-configuration observations, and a new HI dataset combining VLA C+D+GBT (VLA D-configuration and GBT data are from the VLA Galactic Plane Survey) for the whole survey. The HI emission shows clear filamentary substructures at negative velocities with low velocity crowding. The emission at positive velocities is more smeared-out, likely due to higher spatial and velocity crowding of structures at the positive velocities. Compared to the spiral arm model of the Milky Way, the atomic gas follows the Sagittarius and Perseus Arm well, but with significant material in the inter-arm regions. With the C-configuration-only HI+continuum data, we produced a HI optical depth map of the THOR areal coverage from 228 absorption spectra with the nearest-neighbor method. With this $\tau$ map, we corrected the HI emission for optical depth, and the derived column density is 38% higher than the column density with optically thin assumption. The total HI mass with optical depth correction in the survey region is $4.7 \times 10^8 \ M_\sun$, 33% more than the mass derived assuming the emission is optically thin. If we applied this 31% correction to the whole Milky Way, the total atomic gas mass would be $9.4 - 10.5 \times 10^9 \ M_\sun$. Comparing the HI with existing CO data, we find a significant increase in the atomic-to-molecular gas ratio from the spiral arms to the inter-arm regions.

The high-sensitivity and resolution THOR HI dataset provides an important new window on the physical and kinematic properties of gas in the inner Galaxy. Although the optical depth we derive is a lower limit, our study shows that the optical depth correction is significant for HI column density and mass estimation. Together with the OH, RRL and continuum emission from the THOR survey, these new HI data provide the basis for high-angular-resolution studies of the interstellar medium (ISM) in different phases.

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Cloud formation in the atomic and molecular phase: HI self absorption (HISA) towards a Giant Molecular Filament

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Molecular clouds form from the atomic phase of the interstellar medium. However, characterizing the transition between the atomic and the molecular interstellar medium (ISM) is a difficult observational task. Here we address cloud formation processes by combining HI self absorption (HISA) with molecular line data. Column density probability density functions (N-PDFs) are a common tool to examine molecular clouds. One scenario proposed by numerical simulations is that the N-PDF evolves from a log-normal shape at early times to a power-law-like shape at later times. To date, investigations of N-PDFs are mostly limited to the molecular component of the cloud. In this paper, we study the cold atomic component of the giant molecular filament GMF38.1-32.4a (GMF38a, distance=3.4 kpc, length~ 230 pc), calculate its N-PDFs and study its kinematics. We identify an extended HISA feature, which is partly correlated with the $^{13}$CO emission. The peak velocities of the HISA and $^{13}$CO observations agree well on the eastern side of the filament, whereas a velocity offset of approximately 4 km s$^{-1}$ is found on the western side. The sonic Mach number we derive from the linewidth measurements shows that a large fraction of the HISA, which is ascribed to the cold neutral medium (CNM), is at subsonic and transonic velocities. The column density of the CNM part is on the order of $10^{20}$ to $10^{21}$ cm$^{-2}$. The column density of molecular hydrogen, traced by $^{13}$CO, is an order of magnitude higher. The N-PDFs from HISA (CNM), HI emission (the warm and cold neutral medium), and $^{13}$CO (molecular component) are well described by log-normal functions, which is in agreement with turbulent motions being the main driver of cloud dynamics. The N-PDF of the molecular component also shows a power law in the high column-density region, indicating self-gravity. We suggest that we are witnessing two different evolutionary stages within the filament. The eastern subregion seems to be forming a molecular cloud out of the atomic gas, whereas the western subregion already shows high column density peaks, active star formation and evidence of related feedback processes.

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The accretion rates and mechanisms of Herbig Ae/Be stars

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This work presents a spectroscopic study of 163 Herbig Ae/Be stars. Amongst these, we present new data for 30 objects. Stellar parameters such as temperature, reddening, mass, luminosity and age are homogeneously determined. Mass accretion rates are determined from Hα emission line measurements. Our data is complemented with the X-Shooter sample from previous studies and we update results using Gaia DR2 parallaxes giving a total of 78 objects with homogeneously determined stellar parameters and mass accretion rates. In addition, mass accretion rates of
an additional 85 HAeBes are determined. We confirm previous findings that the mass accretion rate increases as a function of stellar mass, and the existence of a different slope for lower and higher mass stars respectively. The mass where the slope changes is determined to be $3.98^{+1.37}_{-0.94} M_{\odot}$. We discuss this break in the context of different modes of disk accretion for low- and high mass stars. Because of their similarities with T Tauri stars, we identify the accretion mechanism for the late-type Herbig stars with the Magnetospheric Accretion. The possibilities for the earlier-type stars are still open, we suggest the Boundary Layer accretion model may be a viable alternative. Finally, we investigated the mass accretion - age relationship. Even using the superior Gaia based data, it proved hard to select a large enough sub-sample to remove the mass dependency in this relationship. Yet, it would appear that the mass accretion does decline with age as expected from basic theoretical considerations.

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Turbulence in a self-gravitating molecular cloud core
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Externally driven interstellar turbulence plays an important role in shaping the density structure in molecular clouds. Here we study the dynamical role of internally driven turbulence in a self-gravitating molecular cloud core. Depending on the initial conditions and evolutionary stages, we find that a self-gravitating core in the presence of gravity-driven turbulence can undergo constant, decelerated, and accelerated infall, and thus has various radial velocity profiles. In the gravity-dominated central region, a higher level of turbulence results in a lower infall velocity, a higher density, and a lower mass accretion rate. As an important implication of this study, efficient reconnection diffusion of magnetic fields against the gravitational drag naturally occurs due to the gravity-driven turbulence, without invoking externally driven turbulence.

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A compendium of distances to molecular clouds in the Star Formation Handbook
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Accurate distances to local molecular clouds are critical for understanding the star and planet formation process, yet distance measurements are often obtained inhomogeneously on a cloud-by-cloud basis. We have recently developed a method which combines stellar photometric data with Gaia DR2 parallax measurements in a Bayesian framework to infer the distances of nearby dust clouds to a typical accuracy of $\sim 5\%$. After refining the technique to target lower latitudes and incorporating deep optical data from DECam in the southern Galactic plane, we have derived a catalog of distances to molecular clouds in Reipurth (2008, Star Formation Handbook, vols I and II) which contains a large fraction of the molecular material in the solar neighborhood. Comparison with distances derived from maser parallax measurements towards the same clouds shows our method produces consistent distances with $\lesssim 10\%$ scatter for clouds across our entire distance spectrum (150 pc – 2.5 kpc). We hope this catalog of homogeneous distances will serve as a baseline for future work.

Accepted by A&A

Observations of Protoplanetary Disk Structures

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The disks that orbit young stars are the essential conduits and reservoirs of material for star and planet formation. Their structures, meaning the spatial variations of the disk physical conditions, reflect the underlying mechanisms that drive those formation processes. Observations of the solids and gas in these disks, particularly at high resolution, provide fundamental insights on their mass distributions, dynamical states, and evolutionary behaviors. Over the past decade, rapid developments in these areas have largely been driven by observations with the Atacama Large Millimeter/submillimeter Array (ALMA). This review highlights the state of observational research on disk structures, emphasizing three key conclusions that reflect the main branches of the field: (1) Relationships among disk structure properties are also linked to the masses, environments, and evolutionary states of their stellar hosts; (2) There is clear, qualitative evidence for the growth and migration of disk solids, although the implied evolutionary timescales suggest the classical assumption of a smooth gas disk is inappropriate; and (3) Small-scale substructures with a variety of morphologies, locations, scales, and amplitudes – presumably tracing local gas pressure maxima – broadly influence the physical and observational properties of disks. The last point especially is reshaping the field, with the recognition that these disk substructures likely trace active sites of planetesimal growth or are the hallmarks of planetary systems at their formation epoch.

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IMPRS Summer School 2020: Planet Formation in Protoplanetary Disks

IMPRS Heidelberg invites early-career scientists to its 15th summer school.

The school will focus on the most relevant aspects of planet formation, including the physics of radiation transfer, hydrodynamics and planet-disk interactions, observations of protoplanetary disks ranging from the near-infrared to radio wavelengths and recent achievements in exoplanet astronomy.

Five distinguished invited lecturers, along with an assortment of local experts, will provide an introduction to the field. In addition to the formal lectures, there will be hands-on sessions to perform simulations on hydrodynamic and radiation transfer. We will provide career discussions, and a variety of social activities.

Topics that are covered include: planet formation models, Monte Carlo radiation transfer, ALMA observations, hydrodynamics using the FARGO3D and PLUTO codes and models of Exoplanets atmospheres.

Scientific organizing committee: Bertram Bitsch, Mario Flock, Paola Pinilla (all at MPIA)

School lecturers: Pablo Benítez Llambay (Niels Bohr Institute, University of Copenhagen), Cornelis P. Dullemond (ITA, University of Heidelberg), Michiel Lambrechts (Lund Observatory), Yamila Miguel (Leiden Observatory), and Catherine Walsh (Leeds University, TBC)

More information at: https://www.imprs-hd.mpg.de/Summer-School

Abstract submission deadline

The deadline for submitting abstracts and other submissions is the first day of the month. Abstracts submitted after the deadline will appear in the following month’s issue.
Summary of Upcoming Meetings

First Stars VI
1 - 6 March 2020 Concepcion, Chile
http://www.astro.udec.cl/FirstStarsVI/

Interstellar Shocks School
22 - 27 March 2020, Les Houches, France
https://www.sciencesconf.org/browse/conference/?confid=8899

Linking Dust, Ice, and Gas in Space
19 - 24 April 2020, Capri Islands, Italy
http://www.frcongressi.it/ecla2020/

AIP Thinkshop on Protoplanetary Disk Chemodynamics
11 - 15 May 2020, Leibnitz Institute for Astrophysics Potsdam, Germany
https://meetings.aip.de/event/1

Planet Formation: From Dust Coagulation to Final Orbital Assembly
1 - 26 June 2020, Munich, Germany
http://www.munich-iapp.de/planetformation

Cool Stars, Stellar Systems, and the Sun 21
21 - 26 June 2020, Toulouse, France
https://coolstars21.github.io/

The Physics of Star Formation: From Stellar Cores to Galactic Scales; 29 June - 3 July 2020, Lyon, France
http://staratlyon.univ-lyon1.fr/en

Illuminating the Dusty Universe: A Tribute to the Work of Bruce Draine
6 - 10 July 2020, Florence, Italy
https://web.astro.princeton.edu/IlluminatingTheDustyUniverse

The Early Phase of Star Formation
12 - 17 July 2020, Ringberg, Germany

Star Formation: From Clouds to Discs - A Tribute to the Career of Lee Hartmann
17 - 20 August 2020, Malahide, Ireland
https://www.dias.ie/cloudstodiscs/

Star Formation in Different Environments 2020
24 - 28 August 2020, Quy Nhon, Vietnam
http://icisequynhon.com/conferences/sfde/

Planetary Science: The Young Solar System
6 - 12 September 2020, Quy Nhon, Vietnam
http://www.icisequynhon.com/conferences/planetary_science/

Wheel of Star Formation: A conference dedicated to Prof. Jan Palouš
14 - 18 September 2020, Prague, Czech Republic
https://janfest2020.asu.cas.cz

Conditions and Impact of Star Formation - Across Times and Scales
28 September - 2 October 2020, Chile
https://astro.uni-koeln.de/symposium-star-formation-2020.html
From Clouds to Planets II: The Astrochemical Link
28 September - 2 October 2020, Berlin, Germany
https://events.mpe.mpg.de/event/12/

The Aftermath of a Revolution: Planet Formation Five Years after HL Tau
7 - 11 December 2020, Chile

Protostars & Planets VII
1 - 7 April 2021, Kyoto, Japan
http://www.ppvii.org

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