THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar/planetary evolution and molecular clouds

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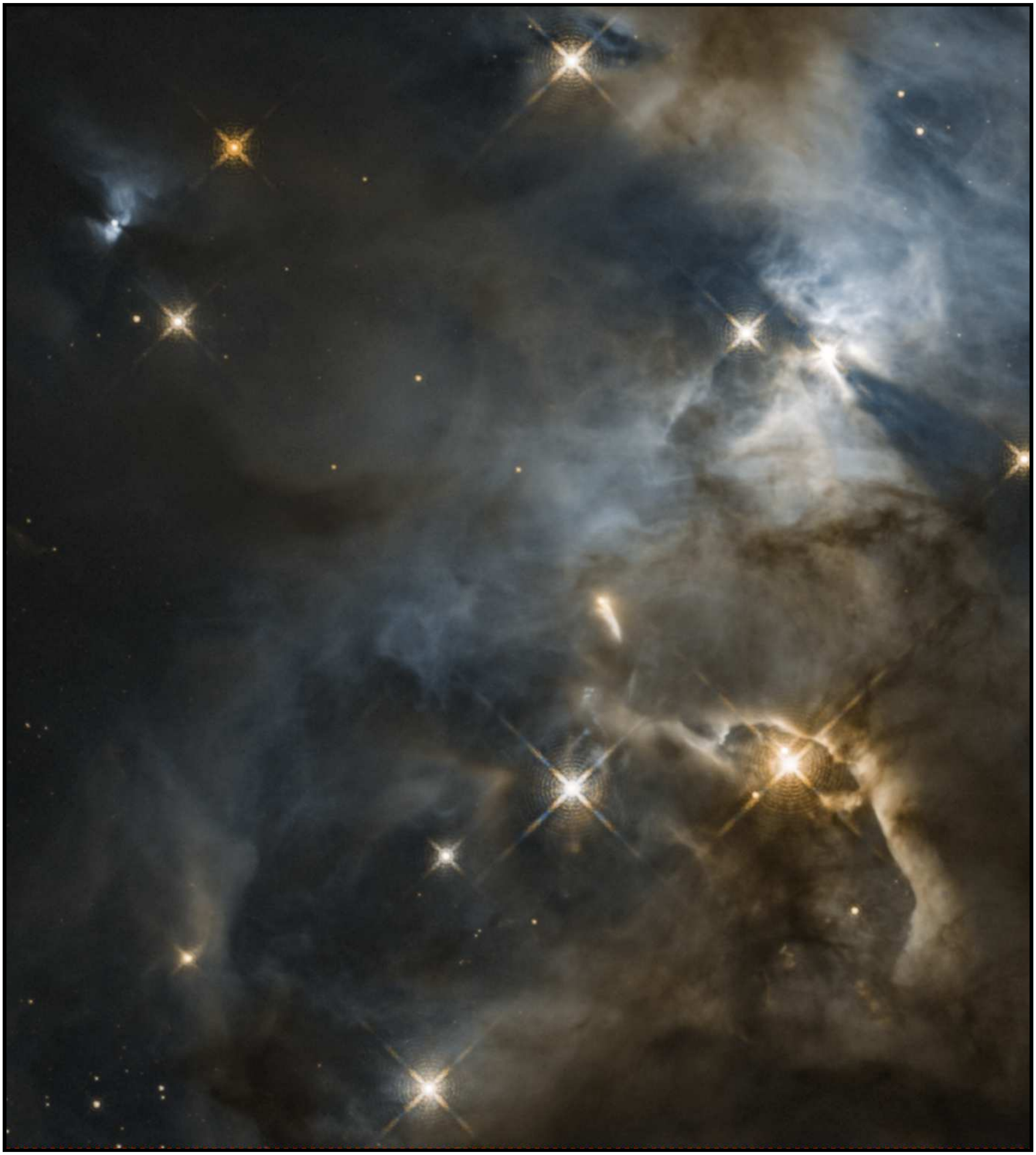

The Star Formation Newsletter

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Cover Picture

HBC 672 is a young low-mass star in the Serpens star forming region, seen here in a WFC3/IR image about 2 arcmin across. Filters are F125W (cyan) and F164N (orange).

Image credit: STScI/M. Mutchler

Submitting your abstracts

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

Typhoon Lee

in conversation with Bo Reipurth

Q: *You won the Trumpler Award for your 1977 PhD thesis. What was the subject and who was your adviser?*

A: My thesis was supervised by Prof. Gerald J. Wasserburg of Caltech, although my degree came from University of Texas at Austin where I studied nuclear astrophysics under Dave Arnett and Dave Schramm. The title of my thesis was "Isotopic Studies of the Allende Meteorite", which resulted in the discovery of the extinct radio-nuclide Al-26.

Specifically I studied Calcium Aluminum rich Inclusions (CAIs) in the Allende meteorite. Although CAIs only constitute a small fraction of the mass of chondrites they are very important, because they preserve information about the physical environment and the processes occurring in the circumsolar disk prior to the formation of the planets. They were the first solid material that formed in the cooling solar nebula.

The unstable short-lived isotope Al-26 decays to Mg-26 thus creating excesses in measured Mg-26/Mg-24 ratios. Large excess Mg-26/Mg-24 up to 10% were found in coexisting phases in CAIs. They correlate linearly with Al-27/Mg-24, indicating that these excess Mg atoms behaved chemically like Al, not Mg, at that time. The evidence for Al-26 in Allende thus implies that this now extinct nuclide was present in the early solar system. We interpreted this result to mean that either a supernova injected material into the solar nebula within the first few million years, or there was an epoch of intense irradiation of the solar nebula by energetic protons from the primeval sun.

Allende was ideal for this study because of its total mass, which is at least 2000kg, while a typical carbonaceous meteorite weighs <1 kg. The decay-product Mg-26 of Al-26 was found in minerals of CAIs, especially those that are coarse grained (>0.1mm) and have a large size (>1g). This allows to maximize the number of experiments that can be performed on the same CAI. The concentration for such large CAIs is probably one large CAI per kg. Thus, Allende can offer around 2,000 large CAIs, while a typical carbonaceous meteorite will bring barely one large CAI. The large size of the sample enabled us to study rare components with unusual properties, such as the discovery that Al-26 had been present in large CAIs during their formation.

In my thesis research I also found Mg as well as Ca isotopic variations in different samples relative to the solar system normal. Before that time, only oxygen and neon were known to be isotopically heterogeneous. One of our samples showed isotopic anomalies in EVERY element, measured until then, from Mg to Sm. Moreover, this sample only deviates from the normal by a few per mil suggesting that it came from the late stage of the mixing of interstellar material. It would be really exciting to learn more, but unfortunately such interesting samples are exceedingly rare, existing at very low levels of 1/100 relative to the number of large CAIs. Therefore, we may never learn what other secrets they could bring us.

Q: *The key result, namely the discovery of the presence of ^{26}Al in the early solar system, was published by you and your collaborators in a paper in 1977. What has happened in this field in the past 40 years?*

A: It has been found that the aluminum in most CAI contained 50 ppm Al-26 when they cooled through their condensation temperature of about 1500C. If we identify this cooling event with the absolute age derived from U-Pb decay, we find that the solar system formed 4.567 ± 0.0005 billion years ago. This is the best (1 per mil error) determination of the age of our solar system. A relative chronology can be built up using the amount of Al-26 in the CAIs with an uncertainty of 0.1 million years.

It is interesting to note that Wasserburg's thesis advisor, Nobel Prize winner Harold Urey, already in the 1950's proposed the importance of Al-26 when it was first produced in the lab. He realized that most meteorites have been heated, some to the point of melting, but that they do not contain enough long lived radioactive nuclei such as U and Th today for these to have been the heat source. Therefore there must have been a transient source of heat such as the short lived isotopes Al-26 or Fe-60 to heat the parent bodies of meteorites in the early solar system. So, this problem has been around for about seven decades.

The origin of Al-26 is still uncertain and its source is best discussed in the frame work of origin of all extinct nuclides. In the early solar system, there have most likely been five radio-nuclides with half lives between 0.1 to 10 Mega-year, they are Be-10, Ca-41, Al-26, Mn-53, and Fe-60. Evidence for Ca-41 has been put into doubt recently. Among the remaining four nuclides, Mn-53 and Al-26 can be produced by either a supernova or an active early sun. The Fe-60 can be made only in the center of supernovae where high temperature and density fuse all nuclides towards the iron peak. On the other hand, Be-10 can be made in the early solar environment by spallation reactions with O-16 and energetic particles from magnetic field reconnection. Note that Be-10 is destroyed in a young star and CANNOT be made anywhere inside the star.

Since Fe-60 seems to be present in the early solar system and Fe-60 can only be made in the core of a supernova, we must conclude that there was at least one nearby supernova explosion when the sun formed.

Q: *You have worked with Frank Shu and Hsien Shang on an astrophysical theory of chondrite formation. What was the basic idea?*

A: At that time, Frank Shu had already suggested that bipolar outflows are driven by high angular momentum gas ejected from an accretion disc, allowing the formation of a young star by the accretion of low angular momentum material. Our paper extends the idea to explore whether the same model can explain the formation of chondrites (the geometric arrangement is shown graphically in our paper in Science in 1996). In this X-wind model, the CAIs are thought initially to be pre-solar dust grains in the molecular cloud. When the cloud accreted towards the inner edge of the disc, the dust was suddenly exposed to the young sun and melted instantly. Thus the fine dust turned to liquid droplets and homogenized internally. These droplets (chondrules and CAIs) also reacted with solar energetic particles to form radio-nuclides such as Al-26 and Be-10. The majority (about 2/3) of this material would fall into the forming sun. The remaining about 1/3 was ejected with the X-wind. Most chondrules then fell back to the disc and accreted toward the central star again. This model implies that most dust in the comet-forming region has been recycled through the central region. Our model is the only one so far that explains the data from NASA's 'Stardust' sample return mission to comet 81P/Wild-2. When examined in the lab, the Stardust data show that instead of being an assemblage of pre-solar grains with large isotopic variation, the vast majority consist of material with normal solar abundances. The best explanation, we believe, is that this material was transferred in the disc to the surface of the sun, melted and homogenized near the sun, recycled to the comet forming region and then rejoining the accretion. Another likely sample of cometary dust are the IDPs - Interplanetary Dust Particles - which are dust collected by highflying airplanes after meteor showers. They show essentially the same results as the dust from 81P/Wild-2, thus also supporting our model.

Perspective

Disks Around O-type Young Stellar Objects

Maite Beltrán

Accretion disks are one of the key ingredients of the star formation process. They redistribute angular momentum and, in the case of high-mass stars ($M > 8\,M_\odot$), disks would relieve the radiation pressure on the accreting material, in particular in the equatorial direction, by beaming the radiation through the poles of the system and this would allow the accretion to proceed onto the central protostar (e.g., Tan et al. 2014 for a review on massive star formation). In fact, in recent years, all high-mass star-forming theories appear to converge to a disk-mediated accretion scenario (e.g., Krumholz et al. 2007; Kuiper et al. 2011; Bonnell & Bate 2006; Keto 2007). But do the observations of high-mass young stellar objects (YSOs) confirm the theory predictions? Or in other words, do true accretion disks around massive stars really exist?

In 2016, Willem-Jan de Wit and myself wrote a review on accretion disks in luminous YSOs to try to answer such questions (Beltrán & de Wit 2016). We concluded that the clear signatures of rotating and/or accretion disks reported in the literature confirmed the existence of circumstellar disks around stars with masses up to 20–30 $M_\odot$ or $\sim 10^5\,L_\odot$, which would correspond to early B-type or late O-type stars (see Fig. 1). The disks of these sources have been spatially resolved using line and continuum tracers from infrared to centimeter wavelengths, and maser emission (e.g., IRAS 20126+4104: Cesaroni et al., 2005, 2014; Cepheus A HW2: Patel et al., 2005; IRAS 13481−6214: Kraus et al., 2010; CRL 2136: de Wit et al., 2011), and their kinematics appear to be consistent, for most cases, with Keplerian rotation (e.g., Bik & Thi, 2004; Blum et al. 2004: Cesaroni et al. 2005, 2014; Wheelwright et al. 2010; Wang et al. 2012; Ilee et al. 2013; Sánchez-Monge et al. 2013; Beltrán et al. 2014). As a result of our study, we also concluded that the accumulated evidence for disks in young OB-type stars did not extend to stars beyond a mass limit of $\sim$30 $M_\odot$, that is, to early O-type stars. Instead, what had been observed towards these sources were more massive ($> 100\,M_\odot$) and larger ($> 10^3$ au) rotating structures called toroids. When we published the study, the ALMA era had just started, and up to then, no high-angular resolution ALMA observations of O-type disk candidates had been yet reported (note that the work by Johnston et al. 2015 appeared when our review was already in press). More than five years later, ALMA has reached an almost complete configuration and long-baseline observations have become available, so, it is time to reformulate our original question and this time confirm or discard the existence of true accretion disks around O-type young stars,, in particular around early O-type stars. If confirmed, this would mean that accretion disks are essential for the formation of stars of all luminosities.

ALMA observations of O-type YSOs

O-type YSOs with $L_{\rm bol} > 10^5\,L_\odot$

Johnston et al. (2015) reported the first candidate disk around an O-type (proto)star of $\sim 2\times10^5\,L_\odot$, AFGL 4176, observed with ALMA. For this source, the emission of CH_3CN, a typical high-density tracer, shows a velocity gradient along the major axis of the source that was consistent with Keplerian-like rotation. The position-velocity (PV) plots show a clear "butterfly" pattern with low-velocity "spurs" and high-velocity spikes close to the position of the embedded protostar, that is consistent with the pattern expected for an edge-on Keplerian disk rotating about a 25 $M_\odot$ O7 star.

Cesaroni et al. (2017) carried out ALMA observations with an angular resolution of $\sim 0.2''$ of a small sample of six star-forming regions containing the most luminous ($L_{\rm bol} > 10^5\,L_\odot$) O-type sources. The observations spatially resolved the CH_3CN emission in seven cores and found evidence of rotation for six of them (G24.78+0.08 A1, G29.96−0.02 HMC, G345.49+1.47 M, G345.50+0.35 M and G345.50+0.35 S). However, only three of them (G29.96−0.02 HMC, G345.50+0.35 M and G345.50+0.35 S) show evidence of Keplerian-like rotation. For one source, G17.64+0.16, these observations did not find any evidence of rotation. Cesaroni et al. (2017) plotted the luminosity-to-mass ratio ($L_{\rm bol}/M_{\rm gas}$), which is an evolutionary stage indicator, versus the distance to the source, including the O-type star AFGL4176, and concluded that the true accretion disk detection rate could be sensitive to the evolutionary stage of the young stellar object. For the youngest sources, the non-detection of Keplerian disks could be due to the fact that the emission of disks is difficult to disentangle from that of the envelopes. Alternatively, disks might start small and grow up with time. On the other hand, for the most evolved source in the sample (G17.64+0.16),

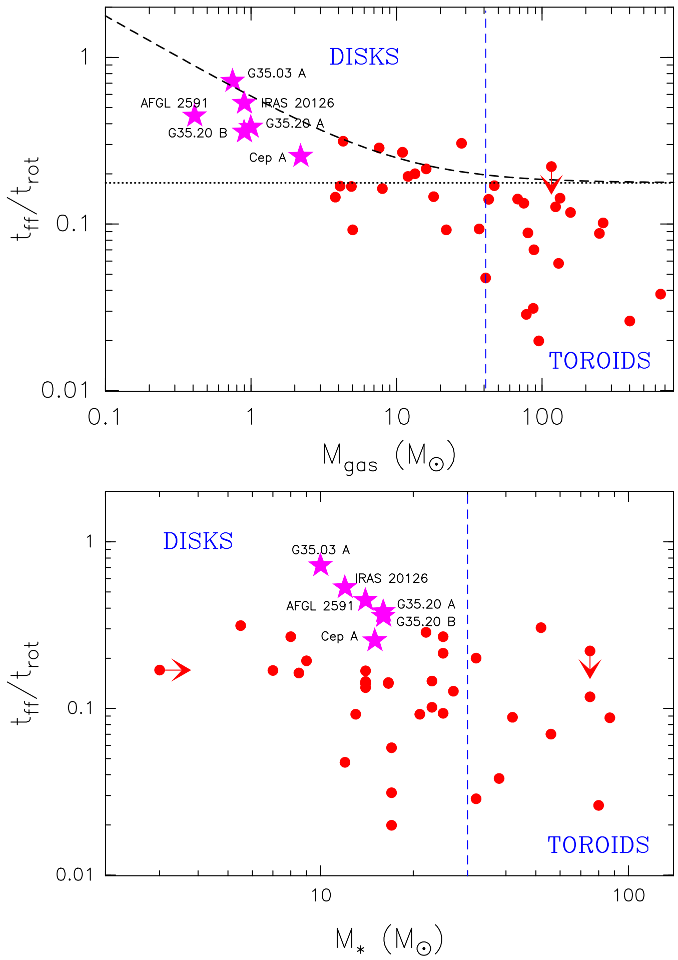

Figure 1: (*Upper panel*) Figure adapted from Beltrán & de Wit (2016). Free-fall timescale to rotational period ratio, $t_{\rm ff}/t_{\rm rot}$, versus $M_{\rm gas}$, of rotating disks or toroids around high-mass (proto)stars. The magenta stars and the labels correspond to the most likely Keplerian disk candidates around B-type (proto)stars. Black dotted and dashed lines correspond to the theoretical values of $t_{\rm ff}/t_{\rm rot}$ for spherical clouds of mass $M_{\rm gas}$ containing a star of mass $M_\star$ at the center, in which the gas is rotationally supported against the gravity of both the gas plus the star. The dotted black line corresponds to $M_\star = 0\,M_\odot$ and the dashed one to $10\,M_\odot$. The blue dashed line indicates a $M_{\rm gas}$ of $40\,M_\odot$. The rotating structures with masses higher than this value are toroids. (*Lower panel*) Same as above but for mass of the central star, $M_\star$, instead. $M_\star$ corresponds to $M_{\star\,\rm cluster}$ of Table 1 of Beltrán & de Wit (2016), which is the mass of the most massive star in the simulated cluster. The blue dashed line, in this case, indicates a $M_\star$ of $30\,M_\odot$.

the molecular gas might have already been dispersed and therefore, no disk is found. This study concluded that only sources with an intermediate evolutionary stage appeared to have true accretion disks clearly detectable in typical hot core tracers.

In the meantime, since the publication of the Cesaroni et al. study, things have slightly changed, in particular for G17.64+0.16, the source, for which no disk evidence was found. Maud et al. (2018) analyzed and modeled the ALMA SiO observations at 0.2″, also covered by the frequency setup of the observations of Cesaroni et al. (2017), and found evidence for a disk in Keplerian rotation around a 10–30 $M_\odot$ YSO. New ALMA observations of H_2O at an even higher angular resolution ($\sim$ 17 mas, which corresponds to a spatial resolution of $\sim$ 38 au), have recently confirmed the existence of a Keplerian disk around a $45 \pm 10\,M_\odot$ O-type (proto)star (Maud et al. 2019). Another source for which things have changed is G31.41+0.31. In this case, new parallax observations (Reid et al. 2019) have located this high-mass star-forming region much closer, at 3.7 kpc. With this new distance estimate, the luminosity of the source would be of $5.7 \times 10^4\,L_\odot$, and therefore, it would not fulfill one of the criteria of selection of the Cesaroni et al. (2017) sample, that is, to have luminosity $> 10^5 L_\odot$.

O-type YSOs with $L_{\rm bol} < 10^5\,L_\odot$

Moving to lower luminosity ($L_{\rm bol} < 10^5\,L_\odot$) O-type YSOs, ALMA observations have revealed new disk candidates. Ilee et al. (2016) carried out millimeter sub-arcsecond SMA observations of the young proto-O star G11.92−0.61 MM1, which is embedded in an infrared dark cloud, and discovered a velocity gradient consistent with Keplerian rotation about a 30–60 $M_\odot$ YSO. The central mass modeled by Ilee et al. (2016) is much higher than the one that would correspond to a luminosity of $10^4\,L_\odot$. Following Beltrán & de Wit (2016) and assuming that $L_{\rm bol}$ is consistent with that of a stellar cluster populated assuming a randomly sampled Chabrier (2005) initial mass function, we estimated that the mass of the most massive star in the simulated cluster would be of 12 $M_\odot$ for such a luminosity. This low luminosity could be due to a high accretion rate in this very young high-mass protostar that would increase the radius of the source and decrease its effective temperature (e.g., Hosokawa & Omukai 2009). Another explanation could be that the SMA observations do not provide high enough angular resolution to properly resolve and model the velocity field around G11.92−0.61 MM1. Ilee et al. (2018) observed the source with ALMA at about five times higher angular resolution and confirm the presence of a disk in Keplerian rotation. The velocity field was fitted with a model of a thin Keplerian disk rotating about a 34–38 $M_\odot$ central YSO, confirming that G11.92−0.61 MM1 is one of the most massive O-type Keplerian disk candidates to date.

Other disk candidates recently discovered with ALMA are G23.01−0.41 (Sanna et al. 2019) and IRAS 16547−4247 (Zapata et al. 2019), both surrounding a central star of

$\sim$20 $M_\odot$. In the first case, Sanna et al. (2019) have reported sub-Keplerian velocities, while in the latter case the spatially resolved asymmetric disk observed by Zapata et al. (2019) would be Keplerian.

On the other hand, several authors have also reported the existence of rotating disk-like structures with velocity gradients that are not (fully) consistent with Keplerian rotation. In particular, Beuther et al. (2017a) observed in CH_3CN the $1.7 \times 10^4\,L_\odot$ O-type YSO G351.77−0.54 with ALMA at an angular resolution of only 60 mas ($\sim$ 130 au) and concluded that although the line emission shows hints of Keplerian rotation, to properly model the velocity field in this region one should take into account also the contribution of infalling and outflowing material. In a similar way, Maud et al. (2017) observed, also in CH_3CN, the W33A MM1-Main O-type YSO with a spatial resolution of $\sim$ 500 au, and found that the emission showed a very complex morphology with a filamentary and spiraling structure that could feed an embedded and not resolved circumstellar disk. After analyzing the velocity field, these authors concluded that Keplerian rotation alone cannot satisfactorily reproduce the kinematic signatures, although the possibility of the existence of a small (<500 au) Keplerian disk embedded in the core cannot be discarded. Finally, although the observations were not carried out with ALMA but with the VLA, it is worth to mention the case of the $8 \times 10^4\,L_\odot$ O-type YSO NGC 7538IRS1 (Beuther et al. 2017b). VLA CH_3OH observations at $\sim$150 au spatial resolution revealed two disk-like structures with velocity gradients consistent with rotation but with no Keplerian signatures. Beuther et al. (2017b) concluded that taking into account the early evolutionary stage of NGC 7538IRS1, which is still undergoing a major accretion phase as indicated by redshifted absorption, the Keplerian disks could still be too small (< 190 au) to be detected and this would be in line with the simulations of Kuiper et al. (2011). In addition, this material should be ionized, as indicated by the presence of hyper-compact HII regions and therefore, the thermal emission of CH_3OH could not be the best tracer of the accreting and rotating putative Keplerian disk.

It is worth to mention here that, as recently demonstrated by Ahmadi et al. (2019), one has to be cautious when ruling out the existence of true accretion disks based on the appearance of the PV plots because Keplerian disks can mimic solid-body rotation when observed with poor angular resolution.

In summary, in recent years very high-angular resolution ALMA (and VLA) observations have revealed velocity gradients consistent with rotation at disk scales in thirteen star-forming regions associated with O-type YSOs, with six of them with luminosity $> 10^5\,L_\odot$, and seven with $< 10^5\,L_\odot$. In a couple of regions, G345.50+0.35 and NGC 7538IRS1, the observations have resolved the line emission in more than one rotating structure. Therefore, the number of rotating disk-like structures is seven for $L_{\rm bol} > 10^5\,L_\odot$ and eight for $L_{\rm bol} < 10^5\,L_\odot$. Finally, five out of seven structures show Keplerian rotation signatures for sources with $L_{\rm bol} > 10^5\,L_\odot$, and three out of eight for sources with $L_{\rm bol} < 10^5\,L_\odot$.

Disk kinematics

Following Cesaroni et al. (2017), with this new statistics on disk-like structures around O-type YSOs, it is possible to investigate whether the presence of true accretion disks around these massive stars is associated with their evolutionary stage. To do this, we estimated the $L_{\rm bol}/M_{\rm gas}$ ratio for each of the thirteen, where the mass of the molecular clump, $M_{\rm gas}$ was computed from the ATLASGAL 870 μm flux density (Schuller et al. 2009) catalogued by Contreras et al. (2013), assuming, like Cesaroni et al. (2017), a dust temperature $T_{\rm dust}$ of 50 K, a dust absorption coefficient $\kappa_{\rm dust}$ of $2\,{\rm cm^2\,g^{-1}}$ at 870 μm (Ossenkopf & Henning 1994), and a gas-to-dust mass ratio of 100. Note that in our case, the masses have been estimated from the flux density obtained from the ATLASGAL catalogue (Contreras et al. 2013), while Cesaroni et al. (2017) estimated the flux density of the sources from the ATLASGAL maps. Therefore, the $L_{\rm bol}/M_{\rm gas}$ values in both cases are slightly different. For NGC 7538IRS1 for which no ATLASGAL data are available, we have used the fluxes of BOLOCAM at 1.1 mm (Ginsburg et al. 2013), using the same $T_{\rm dust}$ of 50 K and a dust absorption coefficient $\kappa_{\rm dust}$ of $1.24\,{\rm cm^2\,g^{-1}}$. Figure 2 is an update of Fig. 29 of Cesaroni et al. (2017), where we plot the $L_{\rm bol}/M_{\rm gas}$ ratio as a function of distance for sources with $L_{\rm bol} > 10^5\,L_\odot$. We have removed G31.41+0.31 from the plot because, with the new distance estimate, its luminosity is of $5.7 \times 10^4\,L_\odot$ and have changed the "status" to G17.64+0.16, after the discovery of a disk with Keplerian rotation signatures by Maud et al. (2018). Unfortunately, no new disk candidates with luminosities $> 10^5\,L_\odot$ have been discovered since the study of Cesaroni et al. (2017). As seen in Fig. 2, the evolutionary trend observed by Cesaroni et al. still holds; that is, O-type stars can be surrounded by true accretion disks, and the fact that such disks are not detected for all of them is because the youngest sources are too deeply embedded to properly disentangle the velocity field of the disk from that of the surrounding envelope or toroid.

To check whether this trend is still valid if one takes into account all O-type sources for which velocity gradients suggestive of rotation have been observed, in Fig. 3 we have plotted the $L_{\rm bol}/M_{\rm gas}$ ratio as a function of distance but this time for sources with $L_{\rm bol} > 10^4\,L_\odot$. As seen in Fig. 3, when taking into account all the O-type sources (early and late) the evolutionary trend disappears and there is no more a correlation between the youth

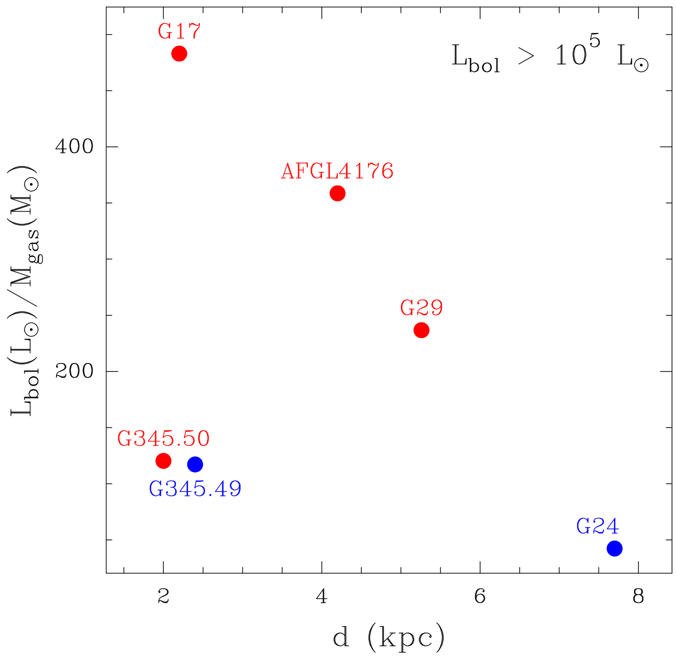

Figure 2: Luminosity-to-mass ratio versus source distance for high-mass star-forming regions with $L_{\rm bol} > 10^5\,L_\odot$. Red and blue points indicate sources with disk candidates (Keplerian rotation) and with questionable disk candidates (no Keplerian rotation evidence), respectively.

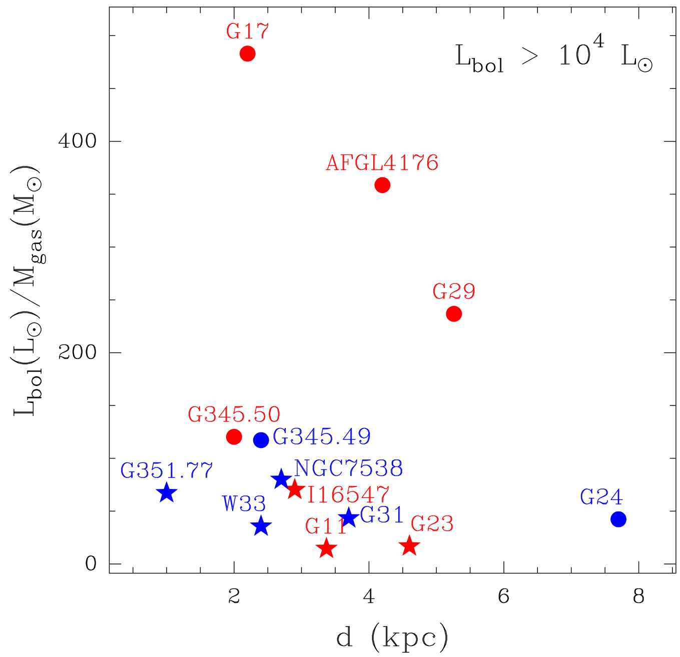

Figure 3: Same as Fig. 2 for high-mass star-forming regions with $L_{\rm bol} > 10^5\,L_\odot$ (*dots*) and $L_{\rm bol} < 10^5\,L_\odot$ (*stars*). Red and blue symbols indicate sources with disk candidates (Keplerian rotation) and with questionable disk candidates (no Keplerian rotation evidence), respectively.

of the YSOs and their lack of accretion disks. In fact, the youngest YSOs, with $L_{\rm bol}/M_{\rm gas} \sim 15$, have Keplerian disks around them. However, while for early O-type YSOs, the $L_{\rm bol}/M_{\rm gas}$ ratio spans more than one order of magnitude, for late O-type sources the range of this ratio is very limited and only ranges from ~ 15 to 80. Therefore, it is more difficult to clearly establish a difference in the evolutionary stage of the sources. In any case, a possible explanation of the fact that Keplerian disks were detected around the younger sources for late O-type YSOs but were not detected for early O-type ones could be due to the fact that the former objects have less material around them and therefore, it is possible to disentangle the surrounding envelope from the disk.

That no Keplerian disks have been found for some late O-type YSOs does not mean that true accretion disks do not exist in these sources. In fact, recent observations suggest that Keplerian accretion disks may be small and hidden on scales < 500 au (e.g., W33A: Maud et al. 2017; NGC 7538IRS1: Beuther et al. 2017b). This would be supported by models and simulations that predict that Keplerian disks, constantly replenished by infalling and rotating material from large-scale non-Keplerian structures, would grow with time, from the inside outward, from ~ 10 au up to $>$1000 au (Kuiper et al. 2011).

Disk substructure and stability

Interestingly, very high angular resolution observations of some Keplerian disk candidates have revealed the existence of substructure in the disk, in the form of spirals (G23.01−0.41: Sanna et al. 2019; AFGL 4176: Johnston et al. 2020) and rings (G17.64+0.16: Maud et al. 2019). ALMA observations at a spatial resolution of ~ 500 au have also revealed a spiral arm in W33A, for which no Keplerian rotation signature has been found (Maud et al. 2017). Spiral arms feeding the central star could develop by the growth of eccentric gravitational instabilities in the star/disk system (the SLING mechanism of Adams et al. 1989) and have been predicted by numerical simulations of disk formation around high-mass YSOs (e.g., Krumholz et al. 2007; Kuiper et al. 2011; Ahmadi et al. 2019). The same simulations show that, at larger scales, spiral structures channel material from the surrounding large-scale infalling envelope onto the embedded circumstellar disk. The latter would be the case of W33A, where the spiral arm observed has been interpreted as an accreting filament that would feed a likely embedded disk with material from the large-scale infalling envelope (Maud et al. 2017).

The stability of the disks against gravitational instabilities can be estimated by means of the Toomre Q parameter (Toomre 1964). According to this stability criterion, a thin disk becomes unstable against axisymmetric gravitational instabilities and prone to fragmentation if $Q < 1$, while non-axisymmetric instabilities, which grow as multi-armed spirals, become unstable for values of Q slightly higher, between 1 and 2 (e.g., Papaloizou & Savonije 1991; Durisen et al. 2007). For AFGL 4176, Johnston et al. (2020) have estimated Q across the disk and have found that the spiral arms are Toomre unstable, with $Q < 2$, and therefore, they could undergo fragmentation. For the other source exhibiting spiral arms, G23.01−0.41, no study of the stability of the disk has been carried out. For the other Keplerian disk candidate showing structure, G17.64+0.16, Maud et al. (2019) conducted a Toomre Q stability analysis, and found the disk, and in particular the rings, to be stable against fragmentation ($Q > 2$). These authors propose that the substructures observed in the disk (the rings) might have formed from fragmentation in an earlier unstable phase. Regarding the other O-type YSOs with rotating structures, a Toomre Q parameter stability study has only been performed for G351.77−0.54 by Beuther et al. (2017a), who, having found $Q > 1.5$, have concluded that the rotating structure should be stable against axisymmetric gravitational fragmentation.

The stability of the rotating structures can also be investigated via the ratio of the mass of the rotating structure and the mass of the central star, $M_{\rm rot}/M_\star$. According to theory, for $M_{\rm rot}/M_\star > 3$, gravitational instabilities that induce spiral density waves appear, leading to a rapid fragmentation of the disk (Laughlin & Bodenheimer 1994; Yorke 1995). We have compiled the $M_{\rm rot}/M_\star$ for those objects for which it has been possible to find an estimate of the mass of the rotating structure, nine out of fifteen. For all but one case (G31.41+0.31), we have found that $M_{\rm rot}/M_\star \lesssim 3$, which would suggest that almost all the rotating structures should be stable. However, because all the observations have been carried out with interferometers at very high-angular resolution, the possibility cannot be discarded that some emission of the rotating structure has been filtered out and, therefore, $M_{\rm rot}$ should be taken as a lower limit.

Conclusions

Accretion disks around high-mass YSOs are fundamental to understand how such stars form. The existence of true accretion disks has been been well established for stars with masses up to $\sim 20\,M_\odot$, which correspond to early B-type or late O-type stars, thanks to the unprecedented angular resolution and sensitivity provided by ALMA in recent years. However, despite the progress made in this field, the number of early O-type (proto)stars ($L > 10^5\,L_\odot$) with Keplerian rotation signatures is still very limited. Up to now, the best true disk candidates are AFLG 4176 and G17.64+0.16 that host a Keplerian disk rotating about a $25\,M_\odot$ and a $45\,M_\odot$ star, respectively (Johnston et al. 2015, 2020; Maud et al. 2018, 2019). G11.92−0.61 MM1 also deserves special mention because despite having a luminosity of only $10^4\,L_\odot$, this source could be hosting a Keplerian disk rotating about a 34–38 $M_\odot$ YSO. The fact that the luminosity of this object is so low is because G11.92−0.61 MM1 is a proto-O star and is still deeply embedded in the parental cloud. These cases are encouraging, but the numbers are still too small to establish, on statistical grounds, that stars of all luminosities are formed via disk-mediated accretion. However, since the Keplerian disk detections around early O-type stars are very recent, the situation is bound to change, and we expect more confirmed cases in the coming years. In particular, when the future baseline expansion of ALMA (aiming at an angular resolution of 0.001″–0.003″) becomes a reality.

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Abstracts of recently accepted papers

Dust clearing by radial drift in evolving protoplanetary disks

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Recent surveys have revealed that protoplanetary disks typically have dust masses that appear to be insufficient to account for the high occurrence rate of exoplanet systems. We demonstrate that this observed dust depletion is consistent with the radial drift of pebbles. Using a Monte Carlo method we simulate the evolution of a cluster of protoplanetary disks, using a 1D numerical method to viscously evolve each gas disk together with the radial drift of dust particles that have grown to 100 μm in size. For a 2 Myr old cluster of stars, we find a slightly sub-linear scaling between the gas disk mass and the gas accretion rate ($M_{\rm g} \propto \dot{M}^{0.9}$). However, for the dust mass we find that evolved dust disks have a much weaker scaling with the gas accretion rate, with the precise scaling depending on the age at which the cluster is sampled and the intrinsic age spread of the disks in the cluster. Ultimately, we find that the dust mass present in protoplanetary disk is on the order of 10–100 Earth masses in 1–3 Myr old star-forming regions, a factor of 10 to 100 depleted from the original dust budget. As the dust drains from the outer disk, pebbles pile up in the inner disk and locally increase the dust-to-gas ratio by a factor of up to 4 above the initial value. In these high dust-to-gas ratio regions we find conditions that are favourable for planetesimal formation via the streaming instability and subsequent growth by pebble accretion. We also find the following scaling relations with stellar mass within a 1–2 Myr old cluster: a slightly super-linear scaling between the gas accretion rate and stellar mass ($\dot{M} \propto {M_\star}^{1.4}$), a slightly super-linear scaling between the gas disk mass and the stellar mass ($M_{\rm g} \propto {M_\star}^{1.4}$) and a super-linear relation between the dust disk mass and stellar mass ($M_{\rm d} \propto {M_\star}^{1.4-4.1}$).

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Radiative Transfer modeling of EC 53: An Episodically Accreting Class I Young Stellar Object

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In the episodic accretion scenario, a large fraction of the protostellar mass accretes during repeated and large bursts of accretion. Since outbursts on protostars are typically identified at specific wavelengths, interpreting these outbursts requires converting this change in flux to a change in total luminosity. The Class I young stellar object EC 53 in the Serpens Main cloud has undergone repeated increases in brightness at 850 μm that are likely caused by bursts of accretion. In this study, we perform two- and three-dimensional continuum radiative transfer modeling to quantify the internal luminosity rise in EC 53 that corresponds to the factor of ∼1.5 enhancement in flux at 850 μm. We model the spectral energy distribution and radial intensity profile in both the quiescent and outburst phases. The internal luminosity in the outburst phase is ∼3.3 times brighter than the luminosity in the quiescent phase. The radial intensity profile analysis demonstrates that the detected sub-mm flux variation of EC 53 comes from the heated envelope by the accretion burst. We also find that the role of external heating of the EC 53 envelope by the interstellar radiation field is insignificant.

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The nature of the methanol maser ring G23.657−00.127. II. Expansion of the maser structure

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Ring-like distributions of the 6.7 GHz methanol maser spots at milliarcsecond scales represent a family of molecular structures of unknown origin associated with high-mass young stellar objects (HMYSOs). We aim to study G23.657−00.127, which has a nearly circular ring of the 6.7 GHz methanol masers, and is the most suitable target to test hypotheses on the origin of the maser rings. The European Very Long Baseline Interferometry Network (EVN) was used at three epochs spanning 10.3 yr to derive the spatio-kinematical structure of the 6.7 GHz methanol maser emission in the target. The maser cloudlets, lying in a nearly symmetric ring, expand mainly in the radial direction with a mean velocity of 3.2 km s^{-1}. There is an indication that the radial component of the velocity increases with cloudlet's distance from the ring centre. The tangential component does not show any clear evidence for rotation of the cloudlets or any relationship with distance from the ring centre. The blue-shifted masers may hint at an anticlockwise rotation of cloudlets in the southern part of the ring. The nearly circular structure of the ring clearly persisted for more than 10 yr. Interferometric data demonstrated that about one quarter of cloudlets show significant variability in their brightness, although the overall spectrum was non-variable in single-dish studies. Taking into account the three-dimensional motion of the maser cloudlets and their spatial distribution along a small ring, we speculate about two possible scenarios where the methanol masers trace either a spherical outflow arising from an (almost) edge-on disc, or a wide angle wind at the base of a protostellar jet. The latter is associated with near- and mid-infrared emission detected towards the ring. High angular resolution images of complementary (thermal) tracers are needed to interpret the environment of methanol masers.

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Dynamical cloud formation traced by atomic and molecular gas

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Context: Atomic and molecular cloud formation is a dynamical process. However, kinematic signatures of these processes are still observationally poorly constrained.
Aims: Identify and characterize the cloud formation signatures in atomic and molecular gas.
Methods: Targeting the cloud-scale environment of the prototypical infrared dark cloud G28.3, we employ spectral line imaging observations of the two atomic lines HI and [CI] as well as molecular lines observations in 13CO in the 1–0 and 3–2 transitions. The analysis comprises investigations of the kinematic properties of the different tracers, estimates of the mass flow rates, velocity structure functions, a Histogram of Oriented Gradients (HOG) study as well as comparisons to simulations.
Results: The central IRDC is embedded in a more diffuse envelope of cold neutral medium (CNM) traced by HI self-absorption (HISA) and molecular gas. The spectral line data as well as the HOG and structure function analysis indicate a possible kinematic decoupling of the HI from the other gas compounds. Spectral analysis and position-velocity diagrams reveal two velocity components that converge at the position of the IRDC. Estimated mass flow rates appear rather constant from the cloud edge toward the center. The velocity structure function analysis is consistent with gas flows being dominated by the formation of hierarchical structures.
Conclusions: The observations and analysis are consistent with a picture where the IRDC G28 is formed at the center of two converging gas flows. While the approximately constant mass flow rates are consistent with a self-similar, gravitationally driven collapse of the cloud, external compression by, e.g., spiral arm shocks or supernovae explosions cannot be excluded yet. Future investigations should aim at differentiating the origin of such converging gas flows.

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Birth of convective low-mass to high-mass second Larson cores

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Stars form as an end product of the gravitational collapse of cold, dense gas in magnetized molecular clouds. This multi-scale scenario occurs via the formation of two quasi-hydrostatic cores and involves complex physical processes, which require a robust, self-consistent numerical treatment. The aim of this study is to understand the formation and evolution of the second Larson core and the dependence of its properties on the initial cloud core mass. We used the PLUTO code to perform high resolution, 1D and 2D RHD collapse simulations. We include self-gravity and use a grey FLD approximation for the radiative transfer. Additionally, we use for the gas EOS density- and temperature-dependent thermodynamic quantities to account for the effects such as dissociation, ionisation, and molecular vibrations and rotations. Properties of the second core are investigated using 1D studies spanning a wide range of initial cloud core masses from 0.5 to 100 $M_{\odot}$. Furthermore, we expand to 2D collapse simulations for a few cases of 1, 5, 10, and 20 $M_{\odot}$. We follow the evolution of the second core for ≥ 100 years after its formation, for each of these non-rotating cases. Our results indicate a dependence of several second core properties on the initial cloud core mass. For the first time, due to an unprecedented resolution, our 2D non-rotating collapse studies indicate that convection is generated in the outer layers of the second core, which is formed due to the gravitational collapse of a 1 $M_{\odot}$ cloud core. Additionally, we find large-scale oscillations of the second accretion shock front triggered by the standing accretion shock instability, which has not been seen before in early evolutionary stages of stars. We predict that the physics within the second core would not be significantly influenced by the effects of magnetic fields or an initial cloud rotation.

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GW Ori: Interactions Between a Triple-star System and its Circumtriple Disk in Action

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GW Ori is a hierarchical triple system with a rare circumtriple disk. We present Atacama Large Millimeter/submillimeter Array (ALMA) observations of 1.3 mm dust continuum and ^{12}CO $J = 2-1$ molecular gas emission of the disk. For the first time, we identify three dust rings in the GW Ori disk at $\sim$ 46, 188, and 338 AU, with estimated dust mass of 74, 168, and 245 Earth masses, respectively. To our knowledge, its outermost ring is the largest dust ring ever found in protoplanetary disks. We use visibility modelling of dust continuum to show that the disk has misaligned parts, and the innermost dust ring is eccentric. The disk misalignment is also suggested by the CO kinematics. We interpret these substructures as evidence of ongoing dynamical interactions between the triple stars and the circumtriple disk.

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Kinematics of T Tauri Stars Close to the Sun from the Gaia DR2 Catalogue

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The spatial and kinematic properties of a large sample of young T Tauri stars from the solar neighborhood 500 pc in radius have been studied. The following parameters of the position ellipsoid have been determined from the most probable members of the Gould Belt: its sizes are $350 \times 270 \times 87$ pc and it is oriented at an angle of $14^\circ \pm 1^\circ$ to the Galactic plane with a longitude of the ascending node of $297^\circ \pm 1^\circ$. An analysis of the motions of stars from this sample has shown that the residual velocity ellipsoid with principal semiaxes $\sigma_{1,2,3} = (8.87, 5.58, 3.03) \pm (0.10, 0.20, 0.04)$ km s^{-1} is oriented at an angle of $22^\circ \pm 1^\circ$ to the Galactic plane with a longitude of the ascending node of $298^\circ \pm 2^\circ$. It has been established that much of the expansion effect (kinematic K effect) typical for Gould Belt stars, 5–6 km s^{-1} kpc^{-1}, can be explained by the influence of a Galactic spiral density wave with a radial perturbation amplitude $f_{\rm R} \sim 5$ km s^{-1}.

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Self-gravitating Filament Formation from Shocked Flows: Velocity Gradients across Filaments

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In typical environments of star-forming clouds, converging supersonic turbulence generates shock-compressed regions, and can create strongly-magnetized sheet-like layers. Numerical MHD simulations show that within these post-shock layers, dense filaments and embedded self-gravitating cores form via gathering material along the magnetic field lines. As a result of the preferred-direction mass collection, a velocity gradient perpendicular to the filament major axis is a common feature seen in simulations. We show that this prediction is in good agreement with recent observations from the CARMA Large Area Star Formation Survey (CLASSy), from which we identified several filaments with prominent velocity gradients perpendicular to their major axes. Highlighting a filament from the northwest part of Serpens South, we provide both qualitative and quantitative comparisons between simulation results and observational data. In particular, we show that the dimensionless ratio $C_v \equiv {\Delta v_h}^2/(GM/L)$, where Δv_h is half of the observed perpendicular velocity difference across a filament, and M/L is the filament's mass per unit length, can distinguish between filaments formed purely due to turbulent compression and those formed due to gravity-induced accretion. We conclude that the perpendicular velocity gradient observed in the Serpens South northwest filament can be caused by gravity-induced anisotropic accretion of material from a flattened layer. Using synthetic observations of our simulated filaments, we also propose that a density-selection effect may explain observed subfilaments (one filament breaking into two components in velocity space) as reported in Dhabal et al. (2018).

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The formation of young massive clusters by colliding flows

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Young massive clusters (YMCs) are the most intense regions of star formation in galaxies. Formulating a model for YMC formation whilst at the same time meeting the constraints from observations is highly challenging however. We show that forming YMCs requires clouds with densities $\gtrsim$ 100 cm^{-3} to collide with high velocities ($\gtrsim$ 20 km s^{-1}). We present the first simulations which, starting from moderate cloud densities of $\sim$ 100 cm^{-3}, are able to convert a large amount of mass into stars over a time period of around 1 Myr, to produce dense massive clusters similar to those observed. Such conditions are commonplace in more extreme environments, where YMCs are common, but atypical for our Galaxy, where YMCs are rare.

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The Gemini Planet Imager view of the HD 32297 debris disk

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We present new H-band scattered light images of the HD 32297 edge-on debris disk obtained with the Gemini Planet Imager (GPI). The disk is detected in total and polarized intensity down to a projected angular separation of 0.15 arcsec, or 20au. On the other hand, the large scale swept-back halo remains undetected, likely a consequence of its markedly blue color relative to the parent body belt. We analyze the curvature of the disk spine and estimate a radius of ≈100au for the parent body belt, smaller than past scattered light studies but consistent with thermal emission maps of the system. We employ three different flux-preserving post-processing methods to suppress the residual starlight and evaluate the surface brightness and polarization profile along the disk spine. Unlike past studies of the system, our high fidelity images reveal the disk to be highly symmetric and devoid of morphological and surface brightness perturbations. We find the dust scattering properties of the system to be consistent with those observed in other debris disks, with the exception of HR 4796. Finally, we find no direct evidence for the presence of a planetary-mass object in the system.

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Gravitoviscous protoplanetary disks with a dust component. III. Evolution of gas, dust, and pebbles

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We study the dynamics and growth of dust particles in circumstellar disks of different masses that are prone to gravitational instability during the critical first Myr of their evolution. The dust component is made up of two different components: micron-sized dust and grown dust of evolving size. For the dust component, we considered the dust coagulation, fragmentation, momentum exchange with the gas, and dust self-gravity. We found that the micron-sized dust particles grow rapidly in the circumstellar disk, reaching a few cm in size in the inner 100 au of the disk during less than 100 kyr after the disk formation, provided that fragmentation velocity is 30 $\mathrm{m\,s^{-1}}$. Due to the accretion of micron dust particles from the surrounding envelope, which serves as a micron dust reservoir, the approximately cm-sized dust particles continue to be present in the disk for more than 900 kyr after the disk formation and maintain a dust-to-gas ratio close to 0.01. We show that a strong correlation exists between the gas and pebble fluxes in the disk. We find that radial surface density distribution of pebbles in the disk shows power-law distribution with an index similar to that of the Minimum-mass solar nebula (MMSN) regardless the disk mass. We also show that the gas surface density in our models agrees well with measurements of dust in protoplanetary disks of AS 209, HD 163296, and DoAr 25 systems. Pebbles are formed during the very early stages of protoplanetary disk evolution. They play a crucial role in the planet formation process. Our disc simulations reveal the early onset ($<10^5$ yr) of an inwards-drifting flux of pebble-sized particles that makes up approximately between one hundredth and one tenth of the gas mass flux, which appears consistent with mm-observations of discs.

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Star Formation Occurs in Dense Gas, but What Does "Dense" Mean?

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We report results of a project to map HCN and HCO^+ J = 1-0 emission toward a sample of molecular clouds in the inner Galaxy, all containing dense clumps that are actively engaged in star formation. We compare these two molecular line tracers with millimeter continuum emission and extinction, as inferred from ^{13}CO, as tracers of dense gas in molecular clouds. The fraction of the line luminosity from each tracer that comes from the dense gas, as measured by $A_V > 8$ mag, varies substantially from cloud to cloud. In all cases, a substantial fraction (in most cases, the majority) of the total luminosity arises in gas below the $A_V > 8$ mag threshold and outside the region of strong mm continuum emission. Measurements of the luminosity of HCN toward other galaxies will likely be dominated by such gas at lower surface density. Substantial, even dominant, contributions to the total line luminosity can arise in

gas with densities typical of the cloud as a whole (densities about 100 cm^{-3}). Defining the dense clump from the HCN or HCO^+ emission itself, similarly to previous studies, leads to a wide range of clump properties, with some being considerably larger and less dense than in previous studies. HCN and HCO^+ have similar ability to trace dense gas for the clouds in this sample. For the two clouds with low virial parameters, the ^{13}CO is definitely a worse tracer of the dense gas, but for the other four, it is equally good (or bad) at tracing dense gas.

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The CARMA-NRO Orion Survey: Protostellar Outflows, Energetics, and Filamentary Alignment

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We identify 45 protostellar outflows in CO maps of the Orion A giant molecular cloud from the CARMA-NRO Orion survey. Our sample includes 11 newly detected outflows. We measure the mass and energetics of the outflows, including material at low-velocities by correcting for cloud contributions. The total momentum and kinetic energy injection rates of outflows is comparable to the turbulent dissipation rate of the cloud. We also compare the outflow position angles to the orientation of $C^{18}O$ filaments. We find that the full sample of outflows is consistent with being randomly oriented with respect to the filaments. A subsample of the most reliable measurements shows a moderately perpendicular outflow-filament alignment which may reflect accretion of mass across filaments and onto the protostellar cores.

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Measuring turbulent motion in planet-forming disks with ALMA: A detection around DM Tau and non-detections around MWC 480 and V4046 Sgr

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Turbulence is a crucial factor in many models of planet formation, but it has only been directly constrained among a small number of planet forming disks. Building on the upper limits on turbulence placed in disks around HD 163296 and TW Hya, we present ALMA CO J=2–1 line observations at $\sim 0''.3$ (20–50 au) resolution and 80 m s^{-1} channel spacing of the disks around DM Tau, MWC 480, and V4046 Sgr. Using parametric models of disk structure, we robustly detect non-thermal gas motions around DM Tau of between 0.25 c_s and 0.33 c_s, with the range dominated by systematic effects, making this one of the only systems with directly measured non-zero turbulence. Using the same methodology, we place stringent upper limits on the non-thermal gas motion around MWC 480 ($<0.08\ c_s$) and V4046 Sgr ($<0.12\ c_s$). The preponderance of upper limits in this small sample, and the modest turbulence levels consistent with dust studies, suggest that weak turbulence ($\alpha \lesssim 10^{-3}$) may be a common, albeit not universal, feature of planet-forming disks. We explore the particular physical conditions around DM Tau that could lead this system to be more turbulent than the others.

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New HST data and modeling reveal a massive planetesimal collision around Fomalhaut

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The apparent detection of an exoplanet orbiting Fomalhaut was announced in 2008. However, subsequent observations of Fomalhaut b raised questions about its status: Unlike other exoplanets, it is bright in the optical and nondetected in the infrared, and its orbit appears to cross the debris ring around the star without the expected gravitational perturbations. We revisit previously published data and analyze additional Hubble Space Telescope (HST) data, finding that the source is likely on a radial trajectory and has faded and become extended. Dynamical and collisional modeling of a recently produced dust cloud yields results consistent with the observations. Fomalhaut b appears to be a directly imaged catastrophic collision between two large planetesimals in an extrasolar planetary system. Similar events should be very rare in quiescent planetary systems of the age of Fomalhaut, suggesting that we are possibly witnessing the effects of gravitational stirring due to the orbital evolution of hypothetical planet(s) around the star.

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HST survey of the Orion Nebula Cluster in the H_2O 1.4 μm absorption band: II. The substellar IMF down to planetary masses

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We exploit the ability of the Hubble Space Telescope to probe near infrared water absorption present in the atmosphere of low-mass stars, brown dwarfs and planetary mass objects to create a very pure sample of Orion Nebula Cluster (ONC) members, not affected by contamination from background stars and galaxies which lack water absorption. Thanks to these data we infer the Initial Mass Function (IMF) of the ONC in the 0.005–1.4 $M_\odot$ regime, i.e. down to few Jupiter masses. The young age of the ONC, $\sim$1 Myr, provides a snapshot of the outcome of star formation for the present-day conditions (metallicity, temperature, pressure) of typical Milky Way disk molecular clouds. We demonstrate that the IMF of the ONC is well described by either a log-normal function or a broken power-law, with parameter values qualitatively in agreement with the canonical Chabrier or Kroupa forms for the Milky Way disk IMF. This continuity in the mass distribution provides clues to the fact that the same physical processes may be regulating formation of stars, brown dwarfs, and planetary mass objects. Both the canonical IMF forms under-predict the observed number of very low mass members (below 0.1 $M_\odot$), a regime where our data allows more precise constraints. Nevertheless, we do not observe a rise or secondary peak in the brown dwarfs or planetary mass regimes. Our study thus contradicts findings based on broad-band near infrared ground-based photometry, which predict an extremely high number of free-floating planets, but likely suffer from unaccounted background contamination.

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Mon-735: A new low-mass pre-main sequence eclipsing binary in NGC 2264

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We present Mon-735, a detached double-lined eclipsing binary (EB) member of the ∼3 Myr old NGC 2264 star forming region, detected by *Spitzer*. We simultaneously model the *Spitzer* light curves, follow-up Keck/HIRES radial velocities, and the system's spectral energy distribution to determine self-consistent masses, radii and effective temperatures for both stars. We find that Mon-735 comprises two pre-main sequence M dwarfs with component masses of $M = 0.2918 \pm 0.0099$ and 0.2661 ± 0.0095 $M_{\odot}$, radii of $R = 0.762 \pm 0.022$ and 0.748 ± 0.023 $R_{\odot}$, and effective temperatures of $T_{\rm eff} = 3260 \pm 73$ and 3213 ± 73 K. The two stars travel on circular orbits around their common centre of mass in $P = 1.9751388 \pm 0.0000050$ days. We compare our results for Mon-735, along with another EB in NGC 2264 (CoRoT 223992193), to the predictions of five stellar evolution models. These suggest that the lower mass EB system Mon-735 is older than CoRoT 223992193 in the mass–radius diagram (MRD) and, to a lesser extent, in the Hertzsprung–Russell diagram (HRD). The MRD ages of Mon-735 and CoRoT 223992193 are ∼7–9 and 4–6 Myr, respectively, with the two components in each EB system possessing consistent ages.

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Molecular globules in the Veil bubble of Orion. IRAM 30m ^{12}CO, ^{13}CO, and C^{18}O 2–1 expanded maps of Orion A

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Strong winds and ultraviolet (UV) radiation from O-type stars disrupt and ionize their molecular core birthplaces, sweeping up material into parsec-size shells. Owing to dissociation by starlight, the thinnest shells are expected to host low molecular abundances and therefore little star formation. Here, we expand previous maps taken with the IRAM 30m telescope and present square-degree ^{12}CO and ^{13}CO (J=2–1) maps of the wind-driven "Veil bubble" that surrounds the Trapezium cluster and its natal Orion molecular core (OMC). Although widespread and extended CO emission is largely absent from the Veil, we show that several CO "globules" exist and are embedded in the [CII]158μm-bright shell that confines the bubble. This includes the first detection of quiescent CO at negative LSR velocities in Orion. Given the harsh UV irradiation conditions in this translucent material, the detection of CO globules is surprising. These globules are small ($R = 7,100$ AU), not massive ($M = 0.3$ $M_{\odot}$), and are moderately dense: $n_{\rm H} = 4 \times 10^4$ cm^{-3} (median values). They are confined by the external pressure of the shell, $P_{\rm ext}/k \sim 10^7$ cm^{-3} K, and are likely magnetically supported. They are either transient objects formed by instabilities or have detached from pre-existing molecular structures, sculpted by the passing shock associated with the expanding shell and by UV radiation from the Trapezium. Some represent the first stages in the formation of small pillars, others of isolated small globules. Although their masses do not suggest they will form stars, one globule matches the position of a known YSO. The lack of extended CO in the "Veil shell" demonstrates that feedback from massive stars expels, agitates, and reprocesses most of the disrupted molecular cloud gas, thereby limiting the star-formation rate in the region. The presence of globules is a result of this feedback.

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Accretion driven turbulence in filaments II: Effects of self-gravity

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We extend our previous work on simulations with the code RAMSES on accretion driven turbulence by including self-gravity and study the effects of core formation and collapse. We show that radial accretion onto filaments drives

turbulent motions which are not isotropic but radially dominated. In contrast to filaments without gravity, the velocity dispersion of self-gravitating filaments does not settle in an equilibrium. Despite showing similar amounts of driven turbulence, they continually dissipate their velocity dispersion until the onset of core formation. This difference is connected to the evolution of the radius as it determines the dissipation rate. In the non-gravitational case filament growth is not limited and its radius grows linearly with time. In contrast, there is a maximum extent in the self-gravitational case resulting in an increased dissipation rate. Furthermore, accretion driven turbulence shows a radial profile which is anti-correlated with density. This leads to a constant turbulent pressure throughout the filament. As the additional turbulent pressure does not have a radial gradient it does not contribute to the stability of filaments and does not increase the critical line-mass. However, this radial turbulence does affect the radius of a filament, adding to the extent and setting its maximum value. Moreover, the radius evolution also affects the growth timescale of cores which compared to the timescale of collapse of an accreting filament limits core formation to high line-masses.

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The H_2O Spectrum of the Massive Protostar AFGL 2136 IRS 1 from 2 to 13 μm at High Resolution: Probing the Circumstellar Disk

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We have observed the massive protostar AFGL 2136 IRS 1 in multiple wavelength windows in the near-to-mid-infrared at high ($\sim$3 km s^{-1}) spectral resolution using VLT+CRIRES, SOFIA+EXES, and Gemini North+TEXES. There is an abundance of H_2O absorption lines from the ν_1 and ν_3 vibrational bands at 2.7 μm, from the ν_2 vibrational band at 6.1 μm, and from pure rotational transitions near 10–13 μm. Analysis of state-specific column densities derived from the resolved absorption features reveals that an isothermal absorbing slab model is incapable of explaining the relative depths of different absorption features. In particular, the strongest absorption features are much weaker than expected, indicating optical depth effects resulting from the absorbing gas being well-mixed with the warm dust that serves as the "background" continuum source at all observed wavelengths. The velocity at which the strongest H_2O absorption occurs coincides with the velocity centroid along the minor axis of the compact disk in Keplerian rotation recently observed in H_2O emission with ALMA. We postulate that the warm regions of this dust disk dominate the continuum emission at near-to-mid infrared wavelengths, and that H_2O and several other molecules observed in absorption are probing this disk. Absorption line profiles are not symmetric, possibly indicating that the warm dust in the disk that produces the infrared continuum has a non-uniform distribution similar to the substructure observed in 1.3 mm continuum emission.

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CAB: Towards the RNA-world in the interstellar medium – detection of urea, and search of 2-amino-oxazole and simple sugars

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In the past decade, Astrochemistry has witnessed an impressive increase in the number of detections of complex organic molecules. Some of these species are of prebiotic interest such as glycolaldehyde, the simplest sugar, or amino acetonitrile, a possible precursor of glycine. Recently, we have reported the detection of two new nitrogen-bearing complex organics, glycolonitrile and Z-cyanomethanimine, known to be intermediate species in the formation process of ribonucleotides within theories of a primordial ribonucleic acid (RNA)-world for the origin of life. In this paper, we present deep and high-sensitivity observations toward two of the most chemically rich sources in the Galaxy: a Giant Molecular Cloud in the center of the Milky Way (G+0.693-0.027) and a proto-Sun (IRAS16293-2422 B). Our aim is to explore whether the key precursors considered to drive the primordial RNA-world chemistry, are also found in space. Our high-sensitivity observations reveal that urea is present in G+0.693-0.027 with an abundance of about 5x10-11. This is the first detection of this prebiotic species outside a star-forming region. Urea remains undetected toward the proto-Sun IRAS16293-2422 B (upper limit to its abundance of less than 2x10-11). Other precursors of the RNA-world chemical scheme such as glycolaldehyde or cyanamide are abundant in space, but key prebiotic species such as 2- amino-oxazole, glyceraldehyde or dihydroxyacetone are not detected in either source. Future more sensitive observations targeting the brightest transitions of these species will be needed to disentangle whether these large prebiotic organics are certainly present in space.

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A Detailed View of the Circumstellar Environment and Disk of the Forming O-star AFGL 4176

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We present a detailed analysis of the disk and circumstellar environment of the forming O-type star AFGL 4176 mm1, placing results from the Atacama Large Millimeter/submillimeter Array (ALMA) into context with multi-wavelength data. With ALMA, we detect seventeen 1.2 mm continuum sources within 5″ (21,000 au) of AFGL 4176 mm1. We find that mm1 has a spectral index of 3.4±0.2 across the ALMA band, with >87 percent of its 1.2 mm continuum emission from dust. The source mm2, projected 4200 au from mm1, may be a companion or a blueshifted knot in a jet. We also explore the morphological differences between the molecular lines with ALMA, detecting 203 lines from 25 molecules, which we categorize into several morphological types. Our results show that AFGL 4176 mm1 provides an example of a forming O-star with a large and chemically complex disk, which is mainly traced by nitrogen-bearing molecules. Lines that show strong emission on the blueshifted side of the disk are predominantly oxygen-bearing, which we suggest are tracing a disk accretion shock. The molecules $C^{34}S$, H_2CS and CH_3CCN trace a slow wide-angle wind or dense structures in the outflow cavity walls. With the Australia Telescope Compact Array (ATCA), we detect a compact continuum source (<2000 × 760 au) at 1.2 cm, associated with mm1, of which >96 percent is from ionized gas. The ATCA NH_3(1,1) and (2,2) emission traces a large-scale (r∼0.5 pc) rotating toroid with the disk source mm1 in the blueshifted part of this structure offset to the NW.

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Unveiling the physical conditions in NGC 6910

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Deep and wide-field optical photometric observations along with multiwavelength archival datasets have been employed to study the physical properties of the cluster NGC 6910. The study also examines the impact of massive stars to their environment. The age, distance and reddening of the cluster are estimated to be ∼4.5 Myr, 1.72±0.08 kpc, and $E(B-V)_{\rm min} = 0.95$ mag, respectively. The mass function slope ($\Gamma = -0.74 \pm 0.15$ in the cluster region is found to be flatter than the Salpeter value (−1.35), indicating the presence of excess number of massive stars. The cluster also shows mass segregation towards the central region due to their formation processes. The distribution of warm dust emission is investigated towards the central region of the cluster, showing the signature of the impact of massive stars within the cluster region. Radio continuum clumps powered by massive B-type stars (age range ∼ 0.07–0.12 Myr) are traced, which are located away from the center of the stellar cluster NGC 6910 (age ∼ 4.5 Myr). Based on the values of different pressure components exerted by massive stars, the photoionized gas associated with the cluster is found to be the dominant feedback mechanism in the cluster. Overall, the massive stars in the cluster might have triggered the birth of young massive B-type stars in the cluster. This argument is supported with evidence of the observed age gradient between the cluster and the powering sources of the radio clumps.

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Self-scattering of non-spherical dust grains

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The understanding of (sub-)millimetre polarisation has made a leap forward since high-resolution imaging with the Atacama Large (sub-)Mm Array (ALMA) came available. Amongst other effects, self-scattering (i.e., scattering of thermal dust emission on other grains) is thought to be the origin of millimetre polarisation. This opens the first window to a direct measurement of dust grain sizes in regions of optically thick continuum emission as it can be found in protoplanetary disks and star-forming regions. However, the newly derived values of grain sizes are usually around ∼100 μm and thus one order of magnitude smaller than those obtained from more indirect measurements as well as those expected from theory (∼1 mm).

We see the origin of this contradiction in the applied dust model of today's self-scattering simulations: a perfect compact sphere. The aim of this study is to test our hypothesis by investigating the impact of non-spherical grain shapes on the self-scattering signal.

We apply discrete dipole approximation simulations to investigate the influence of the grain shape on self-scattering polarisation in three scenarios: an unpolarised and polarised incoming wave under a fixed as well as a varying incident polarisation angle.

We find significant deviations of the resulting self-scattering polarisation when comparing non-spherical to spherical grains. In particular, tremendous deviations are found for the polarisation signal of grains when observed outside the Rayleigh regime, i.e. for >100 μm size grains observed at 870 μm wavelength. Self-scattering by oblate grains produces higher polarisation degrees compared to spheres which challenges the interpretation of the origin of observed millimetre polarisation. A (nearly) perfect alignment of the non-spherical grains is required to account for the observed millimetre polarisation in protoplanetary disks. Furthermore, we find conditions under which the emerging scattering polarisation of non-spherical grains is flipped in orientation by 90°.

These results show clearly that the perfect compact sphere is an oversimplified model which reached its limit. Our findings point towards a necessary re-evaluation of the dust grain sizes derived from (sub-)mm polarisation.

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A family portrait of disk inner rims around Herbig Ae/Be stars: Hunting for warps, rings, self shadowing, and misalignments in the inner astronomical units

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The innermost astronomical unit in protoplanetary disks is a key region for stellar and planet formation, as exoplanet searches have shown a large occurrence of close-in planets that are located within the first au around their host star. We aim to reveal the morphology of the disk inner rim using near-infrared interferometric observations with milli-arcsecond resolution provided by infrared interferometry. We provide reconstructed images of 15 objects selected from the Herbig AeBe survey carried out with PIONIER at the VLTI, using SPARCO. We find that 40% of the systems are centrosymmetric at the angular resolution of the observations. For the rest of the objects, we find evidence for asymmetric emission due to moderate-to-strong inclination of a disk-like structure for 30% of the objects and noncentrosymmetric morphology due to a nonaxisymmetric and possibly variable environment (30%). Among the systems with a disk-like structure, 20% show a resolved dust-free cavity. The image reconstruction process is a powerful tool to reveal complex disk inner rim morphologies. At the angular resolution reached by near-infrared interferometric observations, most of the images are compatible with a centrally peaked emission (no cavity). For the most resolved targets, image reconstruction reveals morphologies that cannot be reproduced by generic parametric models. Moreover, the nonaxisymmetric disks show that the spatial resolution probed by optical interferometers makes the observations of the near-infrared emission sensitive to temporal evolution with a time-scale down to a few weeks. The evidence of nonaxisymmetric emission that cannot be explained by simple inclination and radiative transfer effects requires alternative explanations, such as a warping of the inner disks. Interferometric observations can, therefore, be used to follow the evolution of the asymmetry of those disks at a sub-au scale.

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Formation of secondary atmospheres on terrestrial planets by late disk accretion

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Recently, gas disks have been discovered around main sequence stars well beyond the usual protoplanetary disk lifetimes (i.e., >10 Myrs), when planets have already formed. These gas disks, mainly composed of CO, carbon, and oxygen seem to be ubiquitous in systems with planetesimal belts (similar to our Kuiper belt), and can last for hundreds of millions of years. Planets orbiting in these gas disks will accrete a large quantity of gas that will transform their primordial atmospheres into new secondary atmospheres with compositions similar to that of the parent gas disk. Here, we quantify how large a secondary atmosphere can be created for a variety of observed gas disks and for a wide range of planet types. We find that gas accretion in this late phase is very significant and an Earth's atmospheric mass of gas is readily accreted on terrestrial planets in very tenuous gas disks. In slightly more massive disks, we show that massive CO atmospheres can be accreted, forming planets with up to sub-Neptune-like pressures. Our new results demonstrate that new secondary atmospheres with high metallicities and high C/O ratios will be created in these late gas disks, resetting their primordial compositions inherited from the protoplanetary disk phase, and providing a new birth to planets that lost their atmosphere to photoevaporation or giant impacts. We therefore propose a new paradigm for the formation of atmospheres on low-mass planets, which can be tested with future observations (JWST, ELT, ARIEL). We also show that this late accretion would show a very clear signature in Sub-Neptunes or cold exo-Jupiters. Finally, we find that accretion creates cavities in late gas disks, which could be used as a new planet detection method, for low mass planets a few au to a few tens of au from their host stars.

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The dependence of episodic accretion on eccentricity during the formation of binary stars

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Aims. Investigate how the strength of episodic accretion bursts depends on eccentricity.
Methods. We investigate the binary trigger hypothesis in longer-period (>20yr) binaries by carrying out three-dimensional magnetohydrodynamical (MHD) simulations of the formation of low-mass binary stars down to final separations of ∼10AU, including the effects of gas turbulence and magnetic fields. We run two simulations with an initial turbulent gas core of one solar mass each and two different initial turbulent Mach numbers, $\mathcal{M} = 0.1$ and 0.2, for 6500yr after protostar formation.
Results. We observe bursts of accretion at periastron during the early stages when the eccentricity of the binary system is still high. We find that this correlation between bursts of accretion and passing periastron breaks down at later stages, because of the gradual circularisation of the orbits. For eccentricities greater than $e = 0.2$, we observe episodic accretion triggered near periastron. However, we do not find any strong correlation between the strength (the ratio of the burst accretion ratio to the quiescent accretion rate) of episodic accretion and eccentricity. We determine that accretion events are likely triggered by torques between the rotation of the circumstellar disc and the approaching binary stars. We compare our results with observational data of episodic accretion in short-period binaries and find good agreement between our simulations and the observations.
Conclusions. We conclude that episodic accretion is a universal mechanism operating in eccentric young binary-star systems, independent of separation, and should be observable in long-period binaries as well as in short-period binaries, but that the strength will depend on the torques, and hence the separation at periastron.

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Angular Momenta, Magnetization, and Accretion of Protostellar Cores

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Building on our previous hydrodynamic study of the angular momenta of cloud cores formed during gravitational collapse of star-forming molecular gas in our previous work, we now examine core properties assuming ideal magnetohydrodynamics (MHD). Using the same sink-patch implementation for the *Athena* MHD code, we characterize the statistical properties of cores, including the mass accretion rates, specific angular momenta, and alignments between the magnetic field and the spin axis of the core on the 0.1 pc scale. Our simulations, which reproduce the observed relation between magnetic field strength and gas density, show that magnetic fields can help collimate low density flows and help seed the locations of filamentary structures. Consistent with our previous purely hydrodynamic simulations, stars (sinks) form within the heterogeneous environments of filaments, such that accretion onto cores is highly episodic leading to short-term variability but no long-term monotonic growth of the specific angular momenta. With statistical characterization of protostellar cores properties and behaviors, we aim to provide a starting point for building more realistic and self-consistent disk formation models, helping to address whether magnetic fields can prevent the development of (large) circumstellar disks in the ideal MHD limit.

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On the settling of small grains in dusty discs: analysis and formulas

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Instruments achieve sharper and finer observations of micron-in-size dust grains in the top layers of young stellar discs. To provide accurate models, we revisit the theory of dust settling for small grains, when gas stratification, dust inertia and finite correlation times for the turbulence should be handled simultaneously. We start from a balance of forces and derive distributions at steady-state. Asymptotic expansions require caution since limits do not commute. In particular, non-physical bumpy distributions appear when turbulence is purely diffusive. This excludes very short correlation times for real discs, as predicted by numerical simulations.

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Star Cluster Formation in Orion A

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We introduce new analysis methods for studying the star cluster formation processes in Orion A, especially examining the scenario of a cloud-cloud collision. We utilize the CARMA-NRO Orion survey ^{13}CO (1-0) data to compare molecular gas to the properties of YSOs from the SDSS III IN-SYNC survey. We show that the increase of $v_{13\rm CO} - v_{\rm YSO}$ and Σ scatter of older YSOs can be signals of cloud-cloud collision. SOFIA-upGREAT 158μm [CII] archival data toward the northern part of Orion A are also compared to the ^{13}CO data to test whether the position and velocity offsets between the emission from these two transitions resemble those predicted by a cloud-cloud collision model. We find that the northern part of Orion A, including regions ONC-OMC-1, OMC-2, OMC-3 and OMC-4, shows qualitative agreements with the cloud-cloud collision scenario, while in one of the southern regions, NGC1999, there is no indication of such a process in causing the birth of new stars. On the other hand, another southern cluster, L1641N, shows slight tendencies of cloud-cloud collision. Overall, our results support the cloud-cloud collision process as being an important mechanism for star cluster formation in Orion A.

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A Cold and Diffuse Giant Molecular Filament in the Region of $l = 41°$, $b = -1°$

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Data of ^{12}CO/^{13}CO/C^{18}O $J = 1 \rightarrow 0$ emission toward the Galactic plane region of $l = 35°$ to 45° and $b = -5°$ to +5° are available with the Milky Way Imaging Scroll Painting (MWISP) project. Using the data, we found a giant molecular filament (GMF) around $l \approx 38 \sim 42°$, $b \approx -3.5 \sim 0°$, $V_{LSR} \approx 27 \sim 40$ km s^{-1}, named the GMF MWISP G041-01. At a distance of 1.7 kpc, the GMF is about 160 pc long. With a median excitation temperature about 7.5 K and a median column density about 10^{21} cm^{-2}, this GMF is very cold and very diffuse compared to known GMFs. Using the morphology in the data cube, the GMF is divided into four components among which three show filamentary structure. Masses of the components are $10^3 \sim 10^4 M_\odot$, with a total mass for the whole filament being about $7 \times 10^4 M_\odot$ from the LTE method. ^{13}CO cores inside each component are searched. Virial parameters are about 2.5 for these cores and have a power-law index of -0.34 against the mass. The mass fraction of dense cores traced by ^{13}CO to the diffuse clouds traced by ^{12}CO are about 7% for all components of the GMF. We found signatures of possible large scale filament-filament collision in the GMF.

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Pebble-driven Planet Formation around Very Low-mass Stars and Brown Dwarfs

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We conduct a pebble-driven planet population synthesis study to investigate the formation of planets around very low-mass stars and brown dwarfs, in the (sub)stellar mass range between 0.01 $M_\odot$ and 0.1 $M_\odot$. Based on the extrapolation of numerical simulations of planetesimal formation by the streaming instability, we obtain the characteristic mass of the planetesimals and the initial masses of the protoplanets (largest bodies from the planetesimal size distributions), in either the early self-gravitating phase or the later non-self-gravitating phase of the protoplanetary disk evolution. We find that the initial protoplanets form with masses that increase with host mass, orbital distance and decrease with disk age. Around late M-dwarfs of 0.1 $M_\odot$, these protoplanets can grow up to Earth-mass planets by pebble accretion. However, around brown dwarfs of 0.01 $M_\odot$, planets do not grow larger than Mars mass when the initial protoplanets are born early in self-gravitating disks, and their growth stalls at around 0.01 Earth-mass when they are born late in non-self-gravitating disks. Around these low mass stars and brown dwarfs, we find no channel for gas giant planet formation because the solid cores remain too small. When the initial protoplanets form only at the water-ice line, the final planets typically have $\gtrsim$15% water mass fraction. Alternatively, when the initial protoplanets form log-uniformly distributed over the entire protoplanetary disk, the final planets are either very water-rich (water mass fraction $\gtrsim$15%) or entirely rocky (water mass fraction $\lesssim$5%).

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ALMA Observations of Massive Clouds in the Central Molecular Zone: Jeans Fragmentation and Cluster Formation

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We report ALMA Band 6 continuum observations of 2000 AU resolution toward four massive molecular clouds in the Central Molecular Zone of the Galaxy. To study gas fragmentation, we use the dendrogram method to identify cores as traced by the dust continuum emission. The four clouds exhibit different fragmentation states at the observed resolution despite having similar masses at the cloud scale (∼1–5 pc). Assuming a constant dust temperature of 20 K, we construct core mass functions of the clouds and find a slightly top-heavy shape as compared to the canonical initial mass function, but we note several significant uncertainties that may affect this result. The characteristic spatial separation between the cores as identified by the minimum spanning tree method, $\sim 10^4$ AU, and the characteristic core mass, 1–7 $M_\odot$, are consistent with predictions of thermal Jeans fragmentation. The three clouds showing fragmentation may be forming OB associations (stellar mass $\sim 10^3$ $M_\odot$). None of the four clouds under investigation seem to be currently able to form massive star clusters like the Arches and the Quintuplet ($\gtrsim 10^4$ $M_\odot$), but they may form such clusters by further gas accretion onto the cores.

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Using the Modified Lognormal Power Law Distribution to Model the Mass Function of NGC 1711

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A determination of the mass function (MF) of stellar clusters can be quite dependent on the range of measured masses, the fitting technique, and the analytic function that is being fit to the data. Here, we use HST/WFPC2 data of NGC 1711, a stellar cluster in the Large Magellanic Cloud, as a test case to explore a range of possible determinations of the MF from a single dataset. We employ the analytic modified lognormal power-law (MLP) distribution, a hybrid function that has a peaked lognormal-like body and a power-law tail at intermediate and high masses. A fit with the MLP has the advantage that the resulting best-fit function can be either a hybrid function, a pure lognormal, or a pure power law, in different limits of the function. The completeness limit for the observations means that the data contains masses above $\sim 0.90\,M_\odot$. In this case, the MLP fits yield essentially a pure power-law MF. We demonstrate that the nonlinear regression/least-squares approach is not justified since the underlying assumptions are not satisfied. By using maximum likelihood estimation, which is independent of binning, we find a best-fit functional form $dN/d\ln m \propto m^{-\alpha}$, where $\alpha = 1.72 \pm 0.05$ or 1.75 ± 0.05 for two different theoretical isochrone models, respectively. Furthermore, we explore the possibility of systematic errors in the determination of the power-law index due to the depth of the observations. When we combine the observational data with artificially generated data from the lognormal Chabrier IMF for masses below $0.90\,M_\odot$, the best fit MLP is a hybrid function but with a steeper asymptotic slope i.e., $\alpha = 2.04 \pm 0.07$. This illustrates the systematic uncertainties in commonly used MF parameters that can depend on the range of data that is fitted.

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The Evolution Of The Inner Regions Of Protoplanetary Disks

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We present a study of the evolution of the inner few astronomical units of protoplanetary disks around low-mass stars. We consider nearby stellar groups with ages spanning from 1 to 11 Myr, distributed into four age bins. Combining PANSTARSS photometry with spectral types we derive the reddening consistently for each star, which we use (1) to measure the excess emission above the photosphere with a new indicator of IR excess and (2) to estimate the mass accretion rate ($\dot{M}$) from the equivalent width of the Hα line. Using the observed decay of $\dot{M}$ as a constrain to fix the initial conditions and the viscosity parameter of viscous evolutionary models, we use approximate Bayesian modeling to infer the dust properties that produce the observed decrease of the IR excess with age, in the range between 4.5 and 24 μm. We calculate an extensive grid of irradiated disk models with a two-layered wall to emulate a curved dust inner edge and obtain the vertical structure consistent with the surface density predicted by viscous evolution. We find that the median dust depletion in the disk upper layers is $\epsilon \sim 3 \times 10^{-3}$ at 1.5 Myr, consistent with previous studies, and it decreases to $\epsilon \sim 3 \times 10^{-4}$ by 7.5 Myr. We include photoevaporation in a simple model of the disk evolution and find that a photoevaporative wind mass-loss rate of $\sim 1 - 3 \times 10^{-9}\, M_{\odot} yr^{-1}$ agrees with the decrease of the disk fraction with age reasonably well. The models show the inward evolution of the H_2O and CO snowlines.

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Planet formation by pebble accretion in ringed disks

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Context. Pebble accretion is expected to be the dominant process for the formation of massive solid planets, such as the cores of giant planets and super-Earths. So, far, this process has been studied under the assumption that dust coagulates and drifts throughout the full protoplanetary disk. However, observations show that many disks are structured in rings that may be due to pressure maxima, preventing the global radial drift of the dust.
Aims. We study how the pebble-accretion paradigm changes if the dust is confined in a ring.
Results. Planet Type-I migration is stopped in a ring, but not necessarily at its center. If the entropy-driven corotation torque is desaturated, the planet is located in a region with a low density of dust, which severely limits its accretion rate. If instead the planet is near the ring's center, its accretion rate can be similar to the one it would have in a classic (ring-less) disk of equivalent dust density. However, the growth rate of the planet is limited by the diffusion of dust in the ring and the final planet's mass is bounded by the total ring's mass. The DSHARP rings are too far from the star to allow the formation of massive planets within the disk's lifetime. However, a similar ring rescaled to 5 AU could lead to the formation of a planet incorporating the full ring's mass in less than 1/2 My.
Conclusions. The existence of rings may not be an obstacle to planet formation by pebble-accretion. However, for accretion to be effective the resting position of the planet has to be relatively near the ring's center and the ring needs to be not too far from the central star. The formation of planets in rings can explain the existence of giant planets with core masses smaller than the so-called pebble isolation mass.

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FOREST unbiased Galactic plane imaging survey with the Nobeyama 45 m telescope (FUGIN). VII. molecular fraction of HI clouds

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In this study, we analyze molecular gas formation in neutral atomic hydrogen (HI) clouds using the latest CO data

obtained from the four-beam receiver system on a 45-m telescope (FOREST) unbiased Galactic plane imaging survey with the Nobeyama 45-m telescope (FUGIN) and HI data taken from the Very Large Array (VLA) Galactic plane survey (VGPS). We applied a dendrogram algorithm to the HI data cube to identify HI clouds, and we calculated the HI mass and molecular gas mass by summing the CO line intensity within each HI cloud. On the basis of the results, we created a catalog of 5,737 identified HI clouds with local standard of rest (LSR) velocity of $V_{\rm LSR} \leq -20$ km s^{-1} in Galactic longitude and latitude ranges of $20^\circ \leq l \leq 50^\circ$ and $-1^\circ \leq b \leq 1^\circ$, respectively. We found that most of the HI clouds are distributed within a Galactocentric distance of 16 kpc, most of which are in the Cold Neutral Medium (CNM) phase. In addition, we determined that the high-mass end of the mass HI function is well fitted with the power-law function with an index of 2.3. Although two sequences of self-gravitating and diffuse clouds are expected to appear in the $M_{\rm tot}$-$M_{\rm H_2}$ diagram according to previous works based on a plane-parallel model, the observational data show only a single sequence with large scattering within these two sequences. This implies that most of the clouds are mixtures of these two types of clouds. Moreover, we suggest the following scenario of molecular gas formation: An HI-dominant cloud evolved with increasing H_2 mass along a path of $M_{\rm H_2} \propto {M_{\rm tot}}^2$ by collecting diffuse gas before reaching and moving along the curves of the two sequences.

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TW Hya: an old protoplanetary disc revived by its planet

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Dark rings with bright rims are the indirect signposts of planets embedded in protoplanetary discs. In a recent first, an azimuthally elongated AU-scale blob, possibly a planet, was resolved with ALMA in TW Hya. The blob is at the edge of a cliff-like rollover in the dust disc rather than inside a dark ring. Here we build time-dependent models of TW Hya disc. We find that the classical paradigm cannot account for the morphology of the disc and the blob. We propose that ALMA-discovered blob hides a Neptune mass planet losing gas and dust. We show that radial drift of mm-sized dust particles naturally explains why the blob is located on the edge of the dust disc. Dust particles leaving the planet perform a characteristic U-turn relative to it, producing an azimuthally elongated blob-like emission feature. This scenario also explains why a 10 Myr old disc is so bright in dust continuum. Two scenarios for the dust-losing planet are presented. In the first, a dusty pre-runaway gas envelope of about 40 Earth mass Core Accretion planet is disrupted, e.g., as a result of a catastrophic encounter. In the second, a massive dusty pre-collapse gas giant planet formed by Gravitational Instability is disrupted by the energy released in its massive core. Future modelling may discriminate between these scenarios and allow us to study planet formation in an entirely new way — by analysing the flows of dust and gas recently belonging to planets, informing us about the structure of pre-disruption planetary envelopes.

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2MASS J04435686+3723033 B: A Young Companion at the Substellar Boundary with Potential Membership in the β Pictoris Moving Group

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We present a detailed characterization of 2MASS J04435750+3723031, a low-mass companion orbiting the young M2 star, 2MASS J04435686+3723033, at 7.″6 (550 AU) with potential membership in the 23 Myr β Pictoris moving group (βPMG). Using near-infrared spectroscopy of the companion from IRTF/SpeX we have found a spectral type of M6±1 and indications of youth through age-sensitive absorption lines and a low surface gravity index (VL-G). A young age is supported by Hα emission and lithium absorption in the host. We re-evaluate the membership of this system and find that it is a marginally consistent kinematic match to the βPMG using Gaia parallaxes and new radial velocities for the host and companion. If this system does belong to the βPMG, it would be a kinematic outlier and the companion would be over-luminous compared to other similar ultracool objects like PZ Tel B; this would suggest 2M0443+3723 B could be a close brown dwarf binary (≈52+52 $M_{\rm Jup}$ if equal-flux, compared with 99±5 $M_{\rm Jup}$ if single), and would make it the sixth substellar companion in this group. To test this hypothesis, we acquired NIR AO images with Keck II/NIRC2, but they do not resolve the companion to be a binary down to the diffraction limit of ∼3 AU. If 2M0443+3723 AB does not belong to any moving group then its age is more uncertain. In this case it is still young ($\lesssim$30 Myr), and the implied mass of the companion would be between ∼30–110 $M_{\rm Jup}$.

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HST astrometry in the Orion Nebula Cluster: census of low-mass runaways

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We present a catalog of high-precision proper motions in the Orion Nebula Cluster (ONC), based on Treasury Program observations with the Hubble Space Telescope's (HST) ACS/WFC camera. Our catalog contains 2,454 objects in the magnitude range of $14.2 < m_{\rm F775W} < 24.7$, thus probing the stellar masses of the ONC from ∼0.4 $M_\odot$ down to ∼0.02 $M_\odot$ over an area of ∼550 arcmin^2. We provide a number of internal velocity dispersion estimates for the ONC that indicate a weak dependence on the stellar location and mass. There is good agreement with the published velocity dispersion estimates, although nearly all of them (including ours at $\sigma_{v,x} = 0.94$ and $\sigma_{\rm v,y} = 1.25$ mas yr^{-1}) might be biased by the overlapping young stellar populations of Orion A. We identified 4 new ONC candidate runaways based on HST and the Gaia DR2 data, all with masses less than ∼1 $M_\odot$. The total census of known candidate runaway sources is 10 — one of the largest samples ever found in any Milky Way open star cluster. Surprisingly, none of them has the tangential velocity exceeding 20 km s^{-1}. If most of them indeed originated in the ONC, it may compel re-examination of dynamical processes in very young star clusters. It appears that the mass function of the ONC is not significantly affected by the lost runaways.

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Exocomets: A spectroscopic survey

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While exoplanets are now routinely detected, the detection of small bodies in extrasolar systems remains challenging. Since the discovery of sporadic events interpreted as exocomets (Falling Evaporating Bodies) around β Pic in the early 80s, only $\sim$ 20 stars have been reported to host exocomet-like events. We aim to expand the sample of known exocomet-host stars, as well as to monitor the hot-gas environment around stars with previously known exocometary activity. We have obtained high-resolution optical spectra of a heterogeneous sample of 117 main-sequence stars in the spectral type range from B8 to G8. The data have been collected in 14 observing campaigns expanding over 2 years from both hemispheres. We have analysed the Ca ii K & H and Na i D lines in order to search for non-photospheric absorptions originated in the circumstellar environment, and for variable events that could be caused by outgassing of exocomet-like bodies. We have detected non-photospheric absorptions towards 50% of the sample, attributing a circumstellar origin to half of the detections (i.e. 26% of the sample). Hot circumstellar gas is detected in the metallic lines inspected via narrow stable absorptions, and/or variable blue-/red-shifted absorption events. Such variable events were found in 18 stars in the Ca ii and/or Na i lines; 6 of them are reported in the context of this work for the first time. In some cases the variations we report in the Ca ii K line are similar to those observed in β Pic. While we do not find a significant trend with the age or location of the stars, we do find that the probability of finding CS gas in stars with larger vsin i is higher. We also find a weak trend with the presence of near-infrared excess, and with anomalous (λ Boo-like) abundances, but this would require confirmation by expanding the sample.

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Rotation of Low-Mass Stars in Taurus with K2

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We present an analysis of K2 light curves (LCs) from Campaigns 4 and 13 for members of the young ($\sim$3 Myr) Taurus association, in addition to an older ($\sim$30 Myr) population of stars that is largely in the foreground of the Taurus molecular clouds. Out of 156 of the highest-confidence Taurus members, we find that 81% are periodic. Our sample of young foreground stars is biased and incomplete, but nearly all (37/38) are periodic. The overall distribution of rotation rates as a function of color (a proxy for mass) is similar to that found in other clusters: the slowest rotators are among the early M spectral types, with faster rotation towards both earlier FGK and later M types. The relationship between period and color/mass exhibited by older clusters such as the Pleiades is already in place by Taurus age. The foreground population has very few stars, but is consistent with the USco and Pleiades period distributions. As found in other young clusters, stars with disks rotate on average slower, and few with disks are found rotating faster than $\sim$2 d. The overall amplitude of the light curves decreases with age and higher mass stars have generally lower amplitudes than lower mass stars. Stars with disks have on average larger amplitudes than stars without disks, though the physical mechanisms driving the variability and the resulting light curve morphologies are also different between these two classes.

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HST survey of the Orion Nebula Cluster in the H_2O 1.4 μm absorption band: I. A census of substellar and planetary mass objects

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In order to obtain a complete census of the stellar and sub-stellar population, down to a few $M_{\rm Jup}$ in the ~ 1 Myr old Orion Nebula Cluster, we used the infrared channel of the Wide Field Camera 3 of the Hubble Space Telescope with the F139M and F130N filters. These bandpasses correspond to the 1.4 μm H_2O absorption feature and an adjacent line-free continuum region. Out of 4,504 detected sources, 3,352 (about 75%) appear fainter than $m_{130} = 14$ (Vega mag) in the F130N filter, a brightness corresponding to the hydrogen-burning limit mass ($M \simeq 0.072\ M_\odot$) at ~ 1 Myr. Of these, however, only 742 sources have a negative F130M-139N color index, indicative of the presence of H_2O vapor in absorption, and can therefore be classified as bona-fide M and L dwarfs, with effective temperatures $T \lesssim 2850$ K at an assumed 1 Myr cluster age. On our color-magnitude diagram, this population of sources with H_2O absorption appears clearly distinct from the larger background population of highly reddened stars and galaxies with positive F130M-F139N color index, and can be traced down to the sensitivity limit of our survey, $m_{130} \simeq 21.5$, corresponding to a 1 Myr old $\simeq 3\ M_{\rm Jup}$ planetary mass object under about 2 magnitudes of visual extinction. Theoretical models of the BT-Settl family predicting substellar isochrones of 1, 2 and 3 Myr (down to $\sim 1\ M_{\rm Jup}$) fail to reproduce the observed H_2O color index at $M \lesssim 20\ M_{\rm Jup}$. We perform a Bayesian analysis to determine extinction, mass and effective temperature of each sub-stellar member of our sample, together with its membership probability.

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The efficiency of dust trapping in ringed proto-planetary discs

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When imaged at high-resolution, many proto-planetary discs show gaps and rings in their dust sub-mm continuum emission profile. These structures are widely considered to originate from local maxima in the gas pressure profile. The properties of the underlying gas structures are however unknown. In this paper we present a method to measure the dust-gas coupling α/St and the width of the gas pressure bumps affecting the dust distribution, applying high-precision techniques to extract the gas rotation curve from emission lines data-cubes. As a proof-of-concept, we then apply the method to two discs with prominent sub-structure, HD163296 and AS 209. We find that in all cases the gas

structures are larger than in the dust, confirming that the rings are pressure traps. Although the grains are sufficiently decoupled from the gas to be radially concentrated, we find that the degree of coupling of the dust is relatively good ($\alpha/St \sim 0.1$). We can therefore reject scenarios in which the disc turbulence is very low and the dust has grown significantly. If we further assume that the dust grain sizes are set by turbulent fragmentation, we find high values of the α turbulent parameter ($\alpha \sim 10^{-2}$). Alternatively, solutions with smaller turbulence are still compatible with our analysis if another process is limiting grain growth. For HD163296, recent measurements of the disc mass suggest that this is the case if the grain size is 1mm. Future constraints on the dust spectral indices will help to discriminate between the two alternatives.

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Distance, magnetic field and kinematics of the filamentary cloud LDN 1157

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LDN 1157 is one of the several clouds situated in the cloud complex, LDN 1147/1158. The cloud presents a coma-shaped morphology with a well-collimated bipolar outflow emanating from a Class 0 protostar, LDN 1157-mm, residing deep inside the cloud. The main goals of this work are (a) to map the inter-cloud magnetic field (ICMF) geometry of the region surrounding LDN1157 to investigate its relationship with the cloud morphology, with the outflow direction and with the core magnetic field (CMF) geometry inferred from the mm- and sub-mm polarization results from the literature, and (b) to investigate the kinematic structure of the cloud. We carried out optical (R-band) polarization observations of the stars projected on the cloud to map the parsec-scale magnetic field geometry and made spectroscopic observations of the entire cloud in ^{12}CO, $C^{18}O$ and N_2H^+ (J=1-0) lines to investigate its kinematic structure. We obtained a distance of 340±3 pc to the LDN 1147/1158, complex based on the Gaia DR2 parallaxes and proper motion values of the three young stellar objects (YSOs) associated with the complex. A single filament of ∼1.2 pc in length (traced by the Filfinder algorithm) and ∼0.09 pc in width (estimated using the Radfil algorithm) is found to run all along the coma-shaped cloud. Based on the relationships between the ICMF, CMF, filament orientations, outflow direction, and the presence of an hour-glass morphology of the magnetic field, it is likely that the magnetic field had played an important role in the star formation process in LDN 1157. LDN 1157-mm is embedded in one of the two high density peaks detected using the Clumpfind algorithm. Both the detected clumps are lying on the filament and show a blue-red asymmetry in the ^{12}CO line. The $C^{18}O$ emission is well correlated with the filament and presents a coherent structure in velocity space. Combining the proper motions of the YSOs and the radial velocity of LDN 1147/1158 and an another complex LDN 1172/1174 which is situated ∼2° east of it, we found that both the complexes are moving collectively toward the Galactic plane. The filamentary morphology of the east-west segment of LDN 1157 may have formed as a result of mass lost by ablation due to the interaction of the moving cloud with the ambient interstellar medium.

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A detailed analysis on the cloud structure and dynamics in Aquila Rift

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We present maps in several molecular emission lines of a 1 square-degree region covering the W40 and Serpens South molecular clouds belonging to the Aquila Rift complex. The observations were made with the 45 m telescope at the Nobeyama Radio Observatory. We found that the ^{12}CO and ^{13}CO emission lines consist of several velocity components with different spatial distributions. The component that forms the main cloud of W40 and Serpens South, which we call the "main component", has a velocity of $V_{\rm LSR} \simeq 7$ km s^{-1}. There is another significant component at $V_{\rm LSR} \simeq 40$ km s^{-1}, which we call the "40 km s^{-1} component". The latter component is mainly distributed around two young clusters: W40 and Serpens South. Moreover, the two components look spatially anti-correlated. Such spatial configuration suggests that the star formation in W40 and Serpens South was induced by the collision of the two components. We also discuss a possibility that the 40 km s^{-1} component consists of gas swept up by superbubbles created by SNRs and stellar winds from the Scorpius-Centaurus Association.

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Chandra Resolves the Double FU Orionis System RNO 1B/1C in X-Rays

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We present new *Chandra* X-ray observations of the close pair of young stars RNO 1B and 1C ($6''$ separation) located in the L1287 cloud. RNO 1B erupted in 1978 - 1990 and is classified as an FU Orionis star (FUor). RNO 1C also shows most of the properties of an FUor but no eruption has yet been seen. Only a few dozen FUors are known and the presence of two such objects with a small angular separation is rare, suggesting a common origin. Both stars were faintly detected by *Chandra* and we summarize their X-ray properties within the framework of other previously detected FUors. We also report other X-ray detections in L1287 including the deeply-embedded young star RNO 1G, the jet-like radio source VLA 3, and an enigmatic hard flaring source with no 2MASS counterpart that was only detected in the second of two *Chandra* exposures.

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HST survey of the Orion Nebula Cluster in the H_2O 1.4 μm absorption band: III. The population of sub-stellar binary companions

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We present new results concerning the sub-stellar binary population in the Orion Nebula Cluster (ONC). Using the Karhunen-Loève Image Projection (KLIP) algorithm, we have reprocessed images taken with the IR channel of the Wide Field Camera 3 mounted on the *Hubble Space Telescope* to unveil faint close companions in the wings of the stellar PSFs. Starting with a sample of 1392 bona-fide not saturated cluster members, we detect 39 close-pairs cluster candidates with separation $0.16'' - 0.77''$. The primary masses span a range $M_p \sim 0.015 - 1.27$ $M_\odot$ whereas for the companions we derive $M_c \sim 0.004 - 0.54$ $M_\odot$. Of these 39 binary systems, 18 were already known while the remaining 21 are new detections. Correcting for completeness and combining our catalog with previously detected ONC binaries, we obtain an overall binary fraction of $11.5\% \pm 0.9\%$. Compared to other star forming regions, our multiplicity function is ~ 2 smaller than e.g. Taurus, while compared to the binaries in the field we obtain comparable values. We analyze

the mass function of the binaries, finding differences between the mass distribution of binaries and single stars and between primary and companion mass distributions. The mass ratio shows a bottom-heavy distribution with median value of $M_c/M_p \sim 0.25$. Overall our results suggest that ONC binaries may represent a template for the typical population of field binaries, supporting the hypothesis that the ONC may be regarded as a most typical star forming region in the Milky Way.

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Constraining MHD disk winds with ALMA. Apparent rotation signatures and application to HH212

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Large millimeter interferometers are revealing a growing number of rotating outflows, which are suggested to trace magneto-centrifugal disk winds (MHD DWs). However, their impact on disk accretion is not yet well quantified. Here we identify systematic biases in retrieving the true launch zone, magnetic lever arm, and angular momentum flux of an MHD DW from apparent rotation signatures. Synthetic position-velocity cuts are constructed from self-similar MHD DWs over a broad range of parameters, and three different methods are applied for estimating the specific angular momentum. We find that the launch radius inferred using the well-known relation from Anderson et al. (2006) can markedly differ from the true outermost launch radius r_{out} of the DW. The "double-peak separation" and "flow width" methods provide only a strict lower limit to rout. This bias is independent of angular resolution and can reach a factor ten. In contrast, the "rotation curve" method gives a good estimate of r_{out} when the flow is well resolved, and an upper limit otherwise. The magnetic lever arm is always underestimated. Only comparison with synthetic predictions can take into account properly all observational effects. As an application, we present a comparison with ALMA observations of HH212 at resolutions from 250 au to 16 au, which represents the most stringent observational test of MHD DW to date. This comparison confirms our predicted biases for the double-peak separation method, and the large $r_{out} \sim 40$ au and small magnetic lever arm first suggested by Tabone et al. (2017). We also derive the first accurate analytical expression for the fraction of disk angular momentum extracted by an MHD disk wind of given radial extent, magnetic lever arm, and mass flux. Application to HH212 confirms that MHD DWs are serious candidates for the steady angular momentum extraction process in young disks.

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ALMA ACA and Nobeyama observations of two Orion cores in deuterated molecular lines

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We mapped two molecular cloud cores in the Orion A cloud with the ALMA ACA 7-m Array and with the Nobeyama 45-m radio telescope. These cores have bright N_2D^+ emission in single-pointing observations with the Nobeyama 45-m radio telescope, have relatively high deuterium fraction, and are thought to be close to the onset of star formation. One is a star-forming core, and the other is starless. These cores are located along filaments observed in N_2H^+, and show narrow linewidths of 0.41 km s^{-1} and 0.45 km s^{-1} in N_2D^+, respectively, with the Nobeyama 45-m telescope. Both cores were detected with the ALMA ACA 7m Array in the continuum and molecular lines at Band 6. The starless core G211 shows clumpy structure with several sub-cores, which in turn show chemical differences. Also, the sub-cores in G211 have internal motions that are almost purely thermal. The starless sub-core G211D, in particular, shows a hint of the inverse P Cygni profile, suggesting infall motion. The star-forming core G210 shows an interesting spatial feature of two N_2D^+ peaks of similar intensity and radial velocity located symmetrically with respect to the single dust continuum peak. One interpretation is that the two N_2D^+ peaks represent an edge-on pseudo-disk. The CO outflow lobes, however, are not directed perpendicular to the line connecting both N_2D^+ peaks.

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Protostellar accretion in low mass metal poor stars and the cosmological lithium problem

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The cosmological lithium problem, that is, the discrepancy between the lithium abundance predicted by the Big Bang nucleosynthesis and the one observed for the stars of the 'Spite plateau', is one of the long standing problems of modern astrophysics. Recent hints for a possible solution involve lithium burning induced by protostellar mass accretion on Spite plateau stars.
The purpose of this paper is to analyze the effect of protostellar accretion on low metallicity low-mass stars with a focus

on PMS lithium evolution. We computed the evolution from the protostar to the MS phase of accreting models with final masses of 0.7 and 0.8 $M_\odot$, and three metallicities Z=0.0001, Z=0.0010, and Z=0.0050. The effects of changing the main parameters affecting accreting models, that is the accretion energy (cold versus hot accretion), the initial seed mass $M_{\rm seed}$ and radius $R_{\rm seed}$, and the mass accretion rate $\dot{m}$, have been investigated in detail.
As for the main stellar properties and the surface ^{7}Li abundance, hot accretion models converge to standard non-accreting ones within 1 Myr, regardless of the actual value of $M_{\rm seed}$, $R_{\rm seed}$, and $\dot{m}$. Also, cold accretion models with a relatively large $M_{\rm seed}$ ($\lesssim$10 $M_{\rm jup}$) or $R_{\rm seed}$ ($\lesssim$1 $R_\odot$) converge to standard non-accreting ones in less than about 10–20 Myr. A drastically different evolution occurs whenever a cold protostellar accretion process starts from small values of $M_{\rm seed}$ and $R_{\rm seed}$ ($M_{\rm seed} \sim 1$ $M_{\rm jup}$, $R_{\rm seed} \lesssim 1$ $R_\odot$). These models almost entirely skip the standard Hayashi track evolution and deplete Li before the end of the accretion phase. The exact amount of depletion depends on the actual combination of the accretion parameters ($\dot{m}$, $M_{\rm seed}$, and $R_{\rm seed}$), achieving in some cases the complete exhaustion of Li in the whole star.

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ALMA Observations of Giant Molecular Clouds in M33 I: Resolving Star Formation Activities in the Giant Molecular Filaments Possibly Formed by a Spiral Shock

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We report molecular line and continuum observations toward one of the most massive giant molecular clouds (GMCs), GMC-16, in M33 using ALMA with an angular resolution of $0''44 \times 0''27$ ($\sim$2 pc $\times$ 1 pc). We have found that the GMC is composed of several filamentary structures in ^{12}CO and ^{13}CO (J = 2-1). The typical length, width, and total mass are $\sim$50-70 pc, $\sim$5–6 pc, and $\sim$10^5 $M_\odot$, respectively, which are consistent with those of giant molecular filaments (GMFs) as seen in the Galactic GMCs. The elongations of the GMFs are roughly perpendicular to the direction of the galaxy's rotation, and several H II regions are located at the downstream side relative to the filaments with an offset of $\sim$10–20 pc. These observational results indicate that the GMFs are considered to be produced by a galactic spiral shock. The 1.3 mm continuum and C^{18}O (J = 2-1) observations detected a dense clump with the size of $\sim$2 pc at the intersection of several filamentary clouds, which is referred to as "hub filament," possibly formed by a cloud-cloud collision. A strong candidate for protostellar outflow in M33 also has been identified at the center of the clump. We have successfully resolved the pc-scale local star formation activity in which the galactic scale kinematics may induce the formation of the parental filamentary clouds.

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Protoplanetary disk masses in NGC 2024: Evidence for two populations

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Protoplanetary disks in dense, massive star-forming regions are strongly affected by their environment. How this environmental impact changes over time is an important constraint on disk evolution and external photoevaporation models. We characterize the dust emission from 179 disks in the core of the young (0.5 Myr) NGC 2024 cluster. By studying how the disk mass varies within the cluster, and comparing these disks to those in other regions, we aim to determine how external photoevaporation influences disk properties over time. Using the Atacama Large Millimeter/submillimeter Array, a $2'.9 \times 2'.9$ mosaic centered on NGC 2024 FIR 3 was observed at 225 GHz with a resolution of $0''.25$, or ∼100 AU. The imaged region contains 179 disks identified at IR wavelengths, seven new disk candidates, and several protostars. The overall detection rate of disks is 32±4%. Few of the disks are resolved, with the exception of a giant ($R = 300$ AU) transition disk. Serendipitously, we observe a millimeter flare from an X-ray bright young stellar object (YSO), and resolve continuum emission from a Class 0 YSO in the FIR 3 core. Two distinct disk populations are present: a more massive one in the east, along the dense molecular ridge hosting the FIR 1–5 YSOs, with a detection rate of 45±7%. In the western population, towards IRS 1, only 15±4% of disks are detected. NGC 2024 hosts two distinct disk populations. Disks along the dense molecular ridge are young (0.2–0.5 Myr) and partly shielded from the far ultraviolet radiation of IRS 2b; their masses are similar to isolated 1–3 Myr old SFRs. The western population is older and at lower extinctions, and may be affected by external photoevaporation from both IRS 1 and IRS 2b. However, it is possible these disks had lower masses to begin with.

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Thermal evolution of protoplanetary disks: from β-cooling to decoupled gas and dust temperatures

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Aims. We explore the long-term evolution of young protoplanetary disks with different approaches to computing the thermal structure determined by various cooling and heating processes in the disk and its surroundings.
Methods. Numerical hydrodynamics simulations in the thin-disk limit were complemented with three thermal evolution schemes: a simplified β-cooling approach with and without irradiation, in which the rate of disk cooling is proportional to the local dynamical time, a fiducial model with equal dust and gas temperatures calculated taking viscous heating, irradiation, and radiative cooling into account, and also a more sophisticated approach allowing decoupled dust and gas temperatures.
Results. We found that the gas temperature may significantly exceed that of dust in the outer regions of young disks thanks to additional compressional heating caused by the infalling envelope material in the early stages of disk evolution and slow collisional exchange of energy between gas and dust in low-density disk regions. The outer envelope however shows an inverse trend with the gas temperatures dropping below that of dust. The global disk evolution is only weakly sensitive to temperature decoupling. Nevertheless, separate dust and gas temperatures may affect the chemical composition, dust evolution, and disk mass estimates. Constant-β models without stellar and background irradiation fail to reproduce the disk evolution with more sophisticated thermal schemes because of intrinsically variable nature of the β-parameter. Constant-β models with irradiation can better match the dynamical and thermal evolution, but the agreement is still incomplete.
Conclusions. Models allowing separate dust and gas temperatures are needed when emphasis is placed on the chemical or dust evolution in protoplanetary disks, particularly in sub-solar metallicity environments.

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A new look at Sco OB1 association with Gaia DR2

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We present and discuss photometric optical data in the area of the OB association Sco OB1 covering about 1 squared degree. UBVI photometry is employed in tandem with Gaia DR2 data to investigate the 3 dimensional structure and the star formation history of the region. By combining parallaxes and proper motions we identify 7 physical groups located between the young open cluster NGC 6231 and the bright nebula IC4628. The most prominent group coincides with the sparse open cluster Trumpler 24. We confirm the presence of the intermediate age star cluster VdB-Hagen 202, which is unexpected in this environment, and provide for the first time estimates of its fundamental parameters. After assessing individual groups membership, we derive mean proper motion components, distances, and ages. The seven groups belong to two different families. To the younger family (family I) belong several pre-Main Sequence stars as well. These are evenly spread across the field, and also in front of VdB-Hagen 202. VdB-Hagen 202 and two smaller, slightly detached, groups of similar properties form family II, which do not belong to the association, but are caught in the act of passing through it. As for the younger population, this forms an arc-like structure from the bright nebula IC 4628 down to NGC 6231, as previously found. Moreover, the pre-Main Sequence stars density seems to increase from NGC 6231 northward to Trumpler 24.

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Edge collapse and subsequent longitudinal accretion in Filament S242

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Filament S242 is 25 pc long with massive clumps and YSO clusters concentrated in its end regions; it is considered a good example of edge collapse. We mapped this filament in the ^{12}CO (1–0) and ^{13}CO (1–0) lines. A large-scale velocity gradient along filament S242 has been detected; the relative velocity between the two end-clumps is $\sim$3 km s^{-1}, indicating an approaching motion between them. These signatures are consistent with the filament S242 being formed through the collapse of a single elongated entity, where an effect known as "gravitational focusing" drives the ends of the filament to collapse (edge collapse). Based on this picture, we estimate a collapse timescale of $\sim$4.2 Myr, which is the time needed for a finite and elongated entity evolving to the observed filament S242. For the whole filament, we find that increases in surface densities lead to increases in velocity dispersion, which can be consistently explained as the result of self-gravity. We also calculated the contribution of longitudinal collapse to the observed velocity dispersion and found it to be the dominant effect in driving the gas motion near the end-clumps. We propose that our filament S242 is formed through a two-stage collapse model, where the edge collapse of a truncated filament is followed by a stage of longitudinal accretion toward the dense end-clumps.

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Tidal Interaction between the UX Tauri Disk A/C System Revealed by ALMA

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We present sensitive and high angular resolution (∼0.2-0.3″) (sub)millimeter (230 and 345 GHz) continuum and CO(2−1)/CO(3−2) line archive observations of the disk star system in UX Tauri carried out with ALMA (The Atacama Large Millimeter/Submillimeter Array). These observations reveal the gas and dusty disk surrounding the young star UX Tauri A with a large signal-to-noise ratio (>400 in the continuum and >50 in the line), and for the first time is detected the molecular gas emission associated with the disk of UX Tauri C (with a size for the disk of <56 au). No (sub)millimeter continuum emission is detected at 5σ-level (0.2 mJy at 0.85 mm) associated with UX Tauri C. For the component UX Tauri C, we estimate a dust disk mass of ≤ 0.05 $M_\oplus$. Additionally, we report a strong tidal disk interaction between both disks UX Tauri A/C, separated 360 au in projected distance. The CO line observations reveal marked spiral arms in the disk of UX Tauri A and an extended redshifted stream of gas associated with the UX Tauri C disk. No spiral arms are observed in the dust continuum emission of UX Tauri A. Assuming a Keplerian rotation we estimate the enclosed masses (disk+star) from their radial velocities in 1.4 ± 0.6 $M_\odot$ for UX Tauri A, and 70 ± 30 / $\sin i$ Jupiter masses for UX Tauri C (the latter coincides with the mass upper limit value for a brown dwarf). The observational evidence presented here lead us to propose that UX Tauri C is having a close approach of a possible wide, evolving and eccentric orbit around the disk of UX Tauri A causing the formation of spiral arms and the stream of molecular gas falling towards UX Tauri C.

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The role of Galactic HII regions in the formation of filaments. High-resolution submilimeter imaging of RCW 120 with ArTéMiS

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Massive stars and their associated ionized (HII) regions could play a key role in the formation and evolution of filaments that host star formation. However, the properties of filaments that interact with H regions are still poorly known. To investigate the impact of HII regions on the formation of filaments, we imaged the Galactic HII region RCW 120 and its surroundings where active star formation takes place and where the role of ionization feedback on the star formation process has already been studied. We used the ArTéMiS camera on the APEX telescope and combined the ArTéMiS data at 350 and 450 microns with Herschel-SPIRE/HOBYS. We studied the dense gas distribution around RCW 120 with a resolution of 8″ (0.05 pc at a distance of 1.34 kpc). Our study allows us to trace the median radial intensity profile of the dense shell of RCW 120. This profile is asymmetric, indicating a clear compression from the HII region on the inner part of the shell. The profile is observed to be similarly asymmetric on both lateral sides of the shell, indicating a homogeneous compression over the surface. On the contrary, the profile analysis of a radial filament associated with the shell, but located outside of it, reveals a symmetric profile, suggesting that the compression from the ionized region is limited to the dense shell. The mean intensity profile of the internal part of the shell is well fitted by a Plummer like profile with a deconvolved Gaussian FWHM of 0.09 pc, as observed for filaments in low-mass star-forming regions. This study suggests that compression exerted by HII regions may play a key role in the formation of filaments and may further act on their hosted star formation. ArTéMiS data also suggest that RCW 120 might be a 3D ring, rather than a spherical structure.

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Probing the initial conditions of high-mass star formation — IV. Gas dynamics and NH_2D chemistry in high-mass pre/protocluster clumps

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The initial stage of star formation is very difficult to study because of its high density and low temperature. Under such conditions, many molecules become depleted from the gas phase by freezing out onto dust grains. However, the deuterated species could remain gaseous and are thus ideal tracers. We investigate the gas dynamics and NH_2D chemistry in eight massive pre/protocluster clumps. We present NH_2D 1_{11}–1_{01} (at 85.926 GHz), NH_3 (1, 1) and (2, 2) observations in the eight clumps using the PdBI and the VLA, respectively. We find that the distribution between deuterium fractionation and kinetic temperature shows a number density peak at around $T_{\rm kin}$ = 16.1 K, and the NH_2D cores are mainly located at a temperature range of 13.0 to 22.0 K. We detect seven extremely high deuterium fractionation of $1.0 \lesssim D_{\rm frac} \lesssim 1.41$. We find that the NH_2D emission does not appear to coincide exactly with either dust continuum or NH_3 peak positions, but often surrounds the star-formation active regions. This suggests that the NH_2D has been destroyed by the central young stellar object (YSO) due to its heating. The detected NH_2D lines are very narrow with a median width of 0.98 ± 0.02 km s^{-1}. The extracted NH_2D cores are gravitationally bound ($\alpha_{\rm vir} < 1$), are likely prestellar or starless, and can potentially form intermediate-mass or high-mass stars. Using NH_3 (1, 1) as a dynamical tracer, we find very complicated dynamical movement, which can be explained by a combined process with outflow, rotation, convergent flow, collision, large velocity gradient, and rotating toroids. We find that high deuterium fractionation strongly depends on the temperature condition, and NH_2D is a poor evolutionary indicator of high-mass star formation in evolved stages, but a useful tracer in the starless and prestellar cores.

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http://arxiv.org/pdf/2004.13946

Searching for Molecular Outflows with Support Vector Machines: Dark Cloud Complex in Cygnus

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We present a survey of molecular outflows across the dark cloud complex in the Cygnus region, based on 46.75 deg^2 field of CO isotopologues data from Milky Way Imaging Scroll Painting (MWISP) survey. A supervised machine learning algorithm, Support Vector Machine (SVM), is introduced to accelerate our visual assessment of outflow features in the data cube of ^{12}CO and ^{13}CO $J = 1$–0 emission. A total of 130 outflow candidates are identified, of which 77 show bipolar structures and 118 are new detections. Spatially, these outflows are located inside dense molecular clouds and some of them are found in clusters or in elongated linear structures tracing the underlying gas filament morphology.

Along the line of sight, 97, 31, and 2 candidates reside in the Local, Perseus, and Outer arm, respectively. Young stellar objects as outflow drivers are found near most outflows, while 36 candidates show no associated source. The clusters of outflows that we detect are inhomogeneous in their properties; nevertheless, we show that the outflows cannot inject turbulent energy on cloud scales. Instead, at best, they are restricted to affecting the so called "clump" and "core" scales, and this only on short (∼0.3 Myr) estimated timescales. Combined with outflow samples in the literature, our work shows a tight outflow mass-size correlation.

Accepted by ApJS

http://arxiv.org/pdf/2004.04887

Solid accretion onto planetary cores in radiative disks

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The solid accretion rate, necessary to grow gas giant planetary cores within the disk lifetime, has been a major constraint for theories of planet formation. We tested the solid accretion rate efficiency on planetary cores of different masses embedded in their birth disk, by means of 3D radiation-hydrodynamics, where we followed the evolution of a swarm of embedded solids of different sizes. We found that using a realistic equation of state and radiative cooling, the disk at 5 au is able to cool efficiently and reduce its aspect ratio. As a result, the pebble isolation mass is reached before the core grows to 10 Earth masses, stopping efficiently the pebble flux and creating a transition disk. Moreover, the reduced isolation mass halts the solid accretion before the core reaches the critical mass, leading to a barrier to giant planet formation, and it explains the large abundance of super-Earth planets in the observed population.

Accepted by A&A

http://arxiv.org/pdf/2004.01745

Abstracts of recently accepted major reviews

The molecular cloud lifecycle

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Giant molecular clouds (GMCs) and their stellar offspring are the building blocks of galaxies. The physical characteristics of GMCs and their evolution are tightly connected to galaxy evolution. The macroscopic properties of the interstellar medium propagate into the properties of GMCs condensing out of it, with correlations between e.g. the galactic and GMC scale gas pressures, surface densities and volume densities. That way, the galactic environment sets the initial conditions for star formation within GMCs. After the onset of massive star formation, stellar feedback from e.g. photoionisation, stellar winds, and supernovae eventually contributes to dispersing the parent cloud, depositing energy, momentum and metals into the surrounding medium, thereby changing the properties of galaxies. This cycling of matter between gas and stars, governed by star formation and feedback, is therefore a major driver of galaxy evolution. Much of the recent debate has focused on the durations of the various evolutionary phases that constitute this cycle in galaxies, and what these can teach us about the physical mechanisms driving the cycle. We review results from observational, theoretical, and numerical work to build a dynamical picture of the evolutionary lifecycle of GMC evolution, star formation, and feedback in galaxies.

Accepted by Space Science Reviews

http://arxiv.org/pdf/2004.06113

The Leiden Atomic and Molecular Database (LAMDA): Current status, recent updates, and future plans

Floris van der Tak[1,2], François Lique[3], Alex Faure[4], John H. Black[5], and Ewine F. van Dishoeck[6]

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The Leiden Atomic and Molecular Database (LAMDA) collects spectroscopic information and collisional rate coefficients for molecules, atoms, and ions of astrophysical and astrochemical interest. We describe the developments of the database since its inception in 2005, and outline our plans for the near future. Such a database is constrained both by the nature of its uses and by the availability of accurate data: we suggest ways to improve the synergies among users and suppliers of data. We summarize some recent developments in computation of collisional cross sections and rate coefficients. We consider atomic and molecular data that are needed to support astrophysics and astrochemistry with upcoming instruments that operate in the mid- and far-infrared parts of the spectrum.

Accepted by Atoms (special issue about Atomic and Molecular Databases)

Preprint at https://arxiv.org/pdf/2004.11230

Link to LAMDA database https://home.strw.leidenuniv.nl/$\sim$moldata/

Formation and Evolution of Disks around Young Stellar Objects

Bo Zhao[1], Kengo Tomida[2], Patrick Hennebell[3], John J. Tobin[4], Anaëlle Maury[3], Tomoya Hirota[5], Álvaro Sánchez-Monge[6], Rolf Kuiper[7], Anna Rosen[8], Asmita Bhandare[9], Marco Padovani[10], and Yueh-Ning Lee[11]

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Recent observations have suggested that circumstellar disks may commonly form around young stellar objects. Although the formation of circumstellar disks can be a natural result of the conservation of angular momentum in the parent cloud, theoretical studies instead show disk formation to be difficult from dense molecular cores magnetized to a realistic level, owing to efficient magnetic braking that transports a large fraction of the angular momentum away from the circumstellar region. We review recent progress in the formation and early evolution of disks around young stellar objects of both low-mass and high-mass, with an emphasis on mechanisms that may bridge the gap between observation and theory, including non-ideal MHD effects and asymmetric perturbations in the collapsing core (e.g., magnetic field misalignment and turbulence). We also address the associated processes of outflow launching and the formation of multiple systems, and discuss possible implications in properties of protoplanetary disks.

Accepted by Space Science Reviews, topical collection Star Formation

https://arxiv.org/pdf/2004.01342.pdf

New Jobs

PhD fellowship at IPAG (Grenoble, FR) and MPE (Garching, GE)

We are pleased to announce the availability of one Early Stage Researchers (ESRs) position.

Thesis title:
A new model of the Proto Solar Nebula: organic and molecular fractionation chemistry.

Supervisor:
Prof. C. Ceccarelli (University Grenoble Alpes - IPAG)

Co-Supervisors:
Prof. P. Caselli (Max Planck Institute for Extraterrestrial Studies) and Dr. P. Beck (University Grenoble Alpes - IPAG)

Recruitment Institutions:
the first 18 months at University Grenoble Alpes, Grenoble (France); the second 18 months at Max Planck institute for Extraterrestrial Studies, Garching (Germany)

Doctoral School:
University Grenoble Alpes, Grenoble (France)

Mobility:
The ESR will spend the first 18 months at University Grenoble Alpes (Grenoble, France) and the second 18 months at Max Planck institute for Extraterrestrial Studies (Garching, Germany).

Eligibility:
European and non-European students who have not resided or carried out their main activity (work, studies, ect.) in France for more than 12 months in the 3 years immediately before the recruitment date.

Thesis description:
The formation of the Solar System has left traces in the chemical composition of early-accreted bodies. Particularly rich in this information are the so-called small bodies: comets, asteroids, and their fragments that reach the Earth as meteorites, Interplanetary Dust Particles (IDPs), Trans-Neptunians Objects (TNOs)... Specifically, their content in complex organics as well as the so-called isotopic anomalies turns out to be an extremely useful testimony of what happened to the Solar System at its birth. The goal of the thesis is to construct a model of the early phases of the Proto Solar Nebula (PSN) based on the chemical link between the Solar System small bodies and the currently forming Solar-like planetary systems. To this end, the thesis will develop a model coupling the dynamic evolution of the first phases of the collapse with a dedicated astrochemical model to predict the evolution of organic matter and the molecular fractionation during the earliest phases the Solar System, namely up to the hot corino and the onset of disk phase. The student will include the new reactions studied by the ACO project and make use of the comparison between the model predictions and the observations obtained by ACO members to constrain the model.

The thesis is part of the ACO network, whose ultimate goal is to reconstruct the early history of the Solar System by comparing the chemical composition of presently forming Solar-like planetary systems with that of small bodies in our Solar System. The comparison will be based on the most advanced astrochemical knowledge, which will be developed by the interdisciplinary ACO team.

Requested background:
The successful applicant must have a Master's degree in Physics or Astrophysics or Computer Science or similar by the time of enrollment and be highly motivated. Knowledge of relevant program languages and/or previous experience in astrochemistry and modeling will be appreciated. Excellent Master's degree grades are expected as well as a high level of written and spoken English. Team work ability is essential.

Salary:
The gross amount of the Research fellowship is paid as follows: - for the first 18 months: Euro 2708/month (living allowance) + Euro 430/month (mobility allowance) = Euro 3138 (monthly gross amount) plus possible Family Allowance in addition to coverage of study and research relates expenses; - for the last 18 months: Euro 2599/month. Social security is fully covered. See details on the financial aspects of Marie Sklodowska-Curie-ITN in the Guide for applicants Marie Sklodowska-Curie Actions Innovative Training Networks (ITN) 2018, published at http://ec.europa.eu/research/participants/data/ref/h2020/other/guides_for_applicants/h2020-guide-appl-msca-i

How to apply:
Send the application in pdf format to the address aco-esr17@univ-grenoble-alpes.fr. The application should include a letter of interest, a CV with the marks of the Master year, and at least one recommendation letter, which could also be sent separately to the same e-mail address.

Closing date for application: 2 June 2020 Selection announcement: by 15th June 2020 Expected date of recruitment: between 1 October and 1 December 2020.

Selection procedure:
A short list of candidates will be selected by the 4th June. The short listed candidates will be interviewed the following week and the final selection will be announced by the 15th June.

For more information please look at the website of the project ACO:
https://aco-itn.oapd.inaf.it/job-opportunities

Meetings

Astrochemical Frontiers – Quarantine Edition

Sponsored by IAU Commission H2 Steering Committee:
E. Bergin (President), P. Caselli (Vice-President), J. Jørgensen (Secretary),
Y. Aikawa, M. Cunningham, W. Geppert, K. Öberg, T. Millar (Ex-officio)

Dear Fellow Astrochemists and others interested in the field.

This has been a trying time for all of us throughout the world. There are so many layers to the situation we find ourselves in that the lack of scientific sharing in conferences seems trite. Despite this, we know that there is some wonderful work by numerous scientists that would traditionally be highlighted in an international forum during the summer. Further, there are so many early-career scholars who deserve the opportunity to showcase their work. IAU Commission H2 "Astrochemistry" offers this opportunity via a remote conference (general details on the website below) to give a remote talk, participate in remote questions and answers - and continue to share the science that unites us all.

The meeting will be held on June 15th–19th from 08:00-11:30am EDT (12:00-15:30 GMT) using Zoom. There will be no registration fee, but attendance at the conference will be for admitted registrants only. Talks will be 15 minutes (10 min talk/5 for questions). We will manage the schedule such that talks from Asia will be placed in early slots and US west coast late slots. All talks will be recorded and placed on the conference web site. For those watching the recordings, we will enable Q&A with the speakers during the week of the meeting.

To register and submit an abstract, if desired, fill out the form at the following website:
`https://sites.google.com/cfa.harvard.edu/astrochemicalfrontiers`

- Abstract submission/Registration is due May 18.
- Talks will be announced on May 29.
- Registration will close on June 1.

For questions, you are welcome to contact Ted Bergin (ebergin@umich.edu) or other members of the SOC.

The Physics of Star Formation: from Stellar Cores to Galactic Scales

Dear participants,

We deeply regret to inform you that we have decided to postpone the conference 'The Physics of Star Formation: from Stellar Cores to Galactic Scales' given the continuously evolving situation with Covid19 and the impact it has and will keep having on travels in the near future.

We have been closely monitoring the situation in France and around the world over the last weeks. The situation is evolving at different paces in different countries, making travels and large meetings impossible for the next couple of months. We hope that the epidemic will decline by June, but the safety and health of all participants is our priority. Also, we believe that the situation is not in favour of a postponement until next fall. We thus have decided to postpone the conference to 2022, around the same period (end of June - early July). 2021 is also the year of Protostars and Planets VII where we hope to meet all of you. So please tick already your 2022 agenda at these dates. Meanwhile, we wish the very best to our Japanese colleagues for the PPVII conference !

We deeply thank the SOC, the invited speakers, and all the participants who applied for a contributed slot (180 in total !). All of you participated in developing a promising and high-level program, and we hope to see all of you in Lyon in 2022. The good part of all this involvement is that it should significantly facilitate the organisation of the Star@Lyon 2022.

Benoît Commerçon and Gilles Chabrier

Summary of Upcoming Meetings

Check the websites of these meetings for the latest information on how they are affected by Covid-19

Astrochemical Frontiers – Quarantine Edition
15 - 19 June 2020 via Zoom
https://sites.google.com/cfa.harvard.edu/astrochemicalfrontiers

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

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

The Early Phase of Star Formation
12 - 17 July 2020, Ringberg, Germany
http://www.mpia.de/homes/stein/EPoS/2020/2020.php

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
https://www.eso.org/sci/meetings/2020/hltau2020.html

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

Cool Stars, Stellar Systems, and the Sun 21
postponed to summer 2021, Toulouse, France
https://coolstars21.github.io/

Chemical Processes in Solar-type Star Forming Regions
13 - 17 September 2021, Torino, Italy
https://sites.google.com/inaf.it/aco-conference

The Physics of Star Formation: From Stellar Cores to Galactic Scales
∼June - July 2022, Lyon, France
http:/staratlyon.univ-lyon1.fr/en

Moving ... ??

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

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.