

THE STAR FORMATION NEWSLETTER

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The Star Formation Newsletter

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Cover Picture

IC 417 - aka Sh2-234 - is located almost exactly in the opposite direction from the galactic center. The young cluster Stock 8, seen towards the top of the image, is associated with IC 417. It is at a distance of about 2 kpc and forms part of the OB association Aur OB2. The cover figure shows an infrared image from Spitzer. 2MASS data at 1.2 microns is shown in blue. The Spitzer wavelengths of 3.6 and 4.5 microns are green and red, respectively. Extensive star formation is seen in the lower half of the image.

Courtesy NASA/IPAC

Submitting your abstracts

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifahawaii.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>

Ronald Snell

in conversation with Bo Reipurth



Q: *Back in 1977 you published a paper on self-reversing CO profiles in collapsing molecular clouds. How did your interest in the study of molecular lines originate?*

A: When I began graduate school at the University of Texas my interest was theoretical astrophysics and my first research project was with Craig Wheeler. At the same time I was funded through a research assistantship with David Lambert studying stellar spectra. David suggested that I might work one summer with Paul Vanden Bout and thus by chance I began studies of molecular lines. Paul had a copy of a code, I think from Nick Scoville, to compute the molecular line emission from clouds and gave me the task of making it work. Instead I decided it was easier to write a new code from scratch. Bob Loren, who had just completed his Ph.D., suggested we apply this code to collapsing clouds with an in-fall velocity proportional to $r^{-1/2}$. Such a velocity law has two positions along a given line of sight with the same radial velocity and thus can lead to self-absorption. In clouds where the density and temperature decreased outward (producing an excitation gradient), we found that optically thick lines, such as CO, would have slightly redshifted self-absorption features. Thus the CO line profiles were double-peaked with the blue-peak stronger than the red-peak. Our models matched well the line profiles in four clouds showing self-absorption features and we suggested that this was evidence of non-homologous collapse. Although the application to these clouds may have been incorrect, the concept of what one should observe in non-homologous collapse was sound. This concept was refined later by many researchers using more detailed collapse models to fit the line profiles of thick and thin lines in collapsing cloud cores.

Q: *You finished your thesis in 1979, what was that project about, and who was your adviser?*

A: After that summer, I changed research areas and began working with Paul Vanden Bout. The Millimeter Wave Observatory (MWO) in West Texas was one of the few

facilities available at that time to study millimeter wavelength molecular lines and we had almost unlimited access to observing time. The MWO was already being used for many thesis studies, however no one was using the MWO to study dark clouds, and Paul suggested that this would be a good thesis project. Receiver sensitivity was much poorer back then, and to obtain a reasonable detection of the weak ^{12}CO emission in these dark clouds took at least ten minutes of integration. I selected nine dark clouds for study, eight not known to be forming stars and one with known star formation (L1551 - a fortuitous choice). Large maps (at least for the time) were made of ^{12}CO and ^{13}CO in each cloud requiring hundreds of hours of observing. In addition smaller maps were made of dense gas tracers in the cores. The temperatures, densities, masses, sizes and molecular abundances were derived for each cloud and the radial dependence of the density and temperature were modeled. Line widths were also explored and an early form of the size-line width relation was found.

In these early days of millimeter wavelength astronomy almost any observation could produce new and exciting results. So it was impossible to resist pursuing research beyond my thesis work. I worked with fellow graduate student Al Wootten on a number of projects. One area of particular interest involved deuterated molecules and we made the first detection of DNC. Also with Michel Guélin and Bill Langer we investigated the fractionation process and how this could be used to set an upper limit on the electron density in cloud cores.

Q: *In 1980 you wrote a paper with Robert Loren and Richard Plambeck on a bipolar outflow in the L1551 cloud which has had an enormous impact on star formation studies. What were the circumstances of this discovery?*

A: The only cloud in my thesis sample known to forming stars was L1551. The earlier studies of Gillian Knapp and her colleagues had shown that this cloud had a broad secondary velocity feature offset to the south-west of the infrared source IRS-5 and displaced to lower velocity. They interpreted this broad secondary velocity component as possibly due to collapse. Bob Loren was helping with the CO mapping of this source, as he was now in residence at the MWO. As we extended the map outwards from the center we were surprised to find both red-shifted and blue-shifted broad CO velocity features that arose from a well-defined double-lobed structure centered on the infrared source IRS-5. We later came across a paper by Paul Nachman that made a passing remark about the presence of velocity features at higher velocity. With the help of Dick Plambeck, we used his receiver on the MWO to observe the J=2-1 line from this region. Although the idea of outflows from young stars had already been suggested to explain the broad line wings in Orion, this was the first source to show such clear bipolar structure. We inter-

puted the high velocity gas to be the result of collimated and oppositely directed winds from IRS-5. Associated with the blueshifted outflow lobe were several Herbig-Haro objects, and Richard Schwartz had suggested earlier that H-H-objects might be shocked regions produced by winds from young stars. Kyle Cudworth and George Herbig had just measured the proper motions of the H-H objects in L1551. They found large transverse velocities for these H-H objects and suggested several options for their origin, including that they were accelerated away from IRS-5. Thus the presence of these Herbig-Haro objects fit well with a model in which IRS-5 was producing oppositely directed collimated winds. These winds we believed were responsible for accelerating ambient molecular gas producing the bipolar molecular outflow and producing the shocks responsible for the H-H objects. We were fortunate that this first source was one of the better examples of a bipolar molecular outflow.

Q: *A few years later you summarized your studies of a number of molecular outflows. What were your findings?*

A: After finishing my Ph.D., I moved on to the University of Massachusetts and began a post-doc with the Five College Radio Astronomy Observatory. There I teamed up with Suzan Edwards to search for further connections between molecular outflows and H-H objects using the recently finished FCRAO 14-m telescope. One of our first detections was the bipolar outflow in NGC 1333 associated with HH 7-11. Like L1551, the H-H objects were associated with the blueshifted outflowing gas and this was another example of a well delineated bipolar outflow. Our searches continued yielding a number of outflows associated with H-H objects and we could make a convincing case that high-velocity gas and H-H objects had a common origin in the interaction of stellar winds with the surrounding ambient molecular cloud.

Q: *In the latter half of the 1980s you wrote a number of papers on the structure and kinematics of molecular outflows.*

A: To better understand the structure of molecular outflows, it was important to obtain high signal to noise and high angular resolution observations. To improve the angular resolution of the 14-m telescope, Peter Schloerb and I observed L1551 during a lunar occultation. Later with graduate student Gerald Moriarty-Schieven, we obtained a heavily oversampled map of L1551 that was reconstructed using a maximum entropy algorithm. Based on these data we suggested a model for the L1551 outflow in which the outflowing molecular gas was located in a thin expanding shell which was accelerating away from IRS 5. With Gerald we also obtained high angular resolution images of both the B335 and NGC2071 outflows and suggested they had similar shell structures as L1551.

Q: *You have written a series of papers on water in molecular clouds. What have you learnt?*

A: I was one of the co-investigators on the Submillimeter Wave Astronomy Satellite (SWAS), a NASA Small Explorer mission led by Gary Melnick. The primary science goals were to observe water and molecular oxygen in molecular clouds. When we proposed this mission we expected that SWAS, using the water abundance predicted at that time, would be able to detect the water line from GMC cores in a matter of seconds. The sensitivity of SWAS in orbit was as planned, however it took hours to make a good detection of water, reflecting the lower than expected gas-phase abundance of water. In 2000 we wrote a series of papers presenting SWAS results. We found that in GMC cores the water abundance was several orders of magnitude lower than chemical models at that time predicted and, although we were unable to detect water in dark cloud cores, the upper limits also established a paucity of gas-phase water in these cores. We concluded that gaseous water was not an important reservoir of elemental oxygen in cloud cores. We also speculated that much of elemental oxygen was frozen on dust grains in the form of molecular ices. Subsequent modeling by Dave Hollenbach and colleagues predicted that gaseous water should be present primarily toward the outer layers of clouds where photodesorption can maintain water in the gas phase. Our analysis in 2011, based on the SWAS water maps of Orion, showed that most of gas-phase water was located near the cloud surface, in agreement with this model.

Q: *What have you been doing more recently?*

A: For the past 5 years I, along with co-authors Jon Marr and Stan Kurtz, have been writing a textbook on radio astronomy. The text book, entitled *Fundamentals of Radio Astronomy*, is in two volumes. The first volume (Observational Methods) describes how radio telescopes, interferometers, and radio detectors function as well as how observations are made. The second volume (Astrophysics) describes the production of radio continuum and spectral line emission and specifically how observations at radio wavelengths can be used to determine the properties of HII regions, stars, pulsars, the ISM in the Milky Way and other galaxies, AGNS and the CMB. The first volume was published in 2016 and the second volume was just published in May of this year. Now that this project is finished I have more time for science. The SEQUOIA receiver, which was used for many years on the 14-m telescope, is now installed on the Large Millimeter Telescope and I have a number of projects in the works to continue my studies of the molecular interstellar medium.

My Favorite Object
**Cepheus OB3b: A Story of Two
Expanding Sub-Clusters**

Nicole Karnath



1 Introduction

Our very own Sun likely formed in a cluster that dispersed its stars and natal gas into the disk of the Milky Way (Adams et al. 2001). In fact, Lada & Lada (2003) found that only ~ 7 -10% of young, embedded star clusters survive to form bound, open clusters, while most clusters will self-destruct within a few Myr by expelling their gas, and thus stellar components, into the disk of the Galaxy therefore drastically lowering the gravitational potential of the cluster. The natal gas is presumably expelled via stellar feedback, i.e., ultraviolet radiation and massive stellar winds from OB stars and/or supernovae, the ensuing dynamical evolution will determine whether the cluster - in whole or in part - will form a bound open cluster or disperse into the galactic disk. At a distance of ~ 820 pc (Karnath et al. 2019, hereafter: K19), Cepheus OB3b is a unique cluster to observationally constrain the brief stage of a cluster undergoing gas dispersal, which is thought to be the main mechanism for unbinding stars from a cluster. Analyses of Cep OB3b give a snapshot of cluster evolution toward the end of gas dispersal and at a later stage of evolution than, for example, the Orion Nebula Cluster (ONC), which is of comparable size and membership.

The first study of Cepheus OB3b, (Cep OB3b, see Fig. 1), came from Blaauw et al. (1959), finding one O star (O7V, HD 217086) and several B stars throughout the entire cluster. Sargent (1977) and Heyer et al. (1996) followed up finding two distinct molecular clumps of gas within the larger Cep OB3 molecular cloud. The approximate locations of the two gas clumps are shown as blue circles in Fig 1. These also correspond to what appear to be two distinct sub-clusters in Cep OB3b, henceforth

referred to as the east and west sub-clusters. Each sub-cluster is surrounded by a lower density halo of stars. A large number of stars in Cep OB3b are optically visible (Fig. 1, upper panel) indicating that some degree of gas clearing has already occurred in the region.

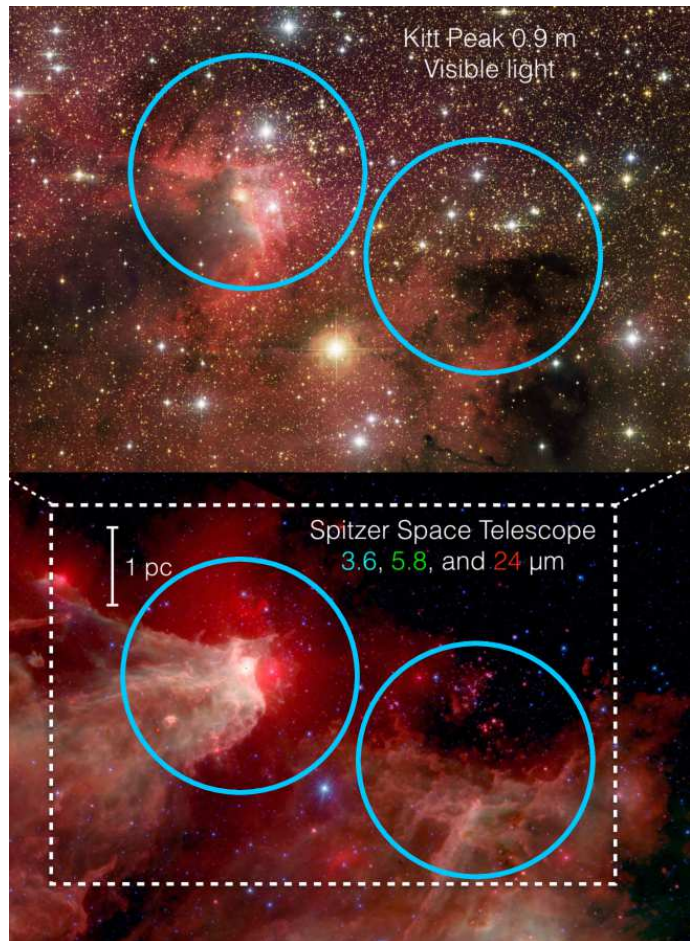


Figure 1: **Top:** A visible light image of Cep OB3b from the 0.9-m on Kitt peak. The four filters used were blue, visual (cyan), near infrared (orange), and an emission line of hydrogen (red). Image credit: NOAO. **Bottom:** The Cepheus OB3 cloud including the Cep A, B, C, D, and E at 3.6, 5.8, and 24 μm via *Spitzer*. The blue circles correspond to the locations of the east and west sub-clusters.

Pozzo et al. (2003) pointed out that there was evidence of a supernova remnant in the east sub-cluster, possibly explaining the structural differences of the two sub-clusters. Getman et al. (2009) used *Spitzer* and *Chandra* to identify, ~ 600 mid-infrared sources and IR-excess low-mass members in Cep OB3b. It was proposed that the O7 star is creating a radiative driven implosion (RDI) in the rim of the associated molecular clump resulting in continued star formation along the edge of the east sub-cluster. More re-

cently, Allen et al. (2012) carried out a census of the young stellar objects (YSOs) in Cep OB3b employing *Spitzer* data, a combination of new and archival *Chandra* data, and visible light photometry from the literature to identify stars on the Cep OB3b isochrone.

Cluster ages have been reported in the literature ranging from 3–5 Myr (Nayler et al. 2001; Pozzo et al. 2003; Littlefair et al. 2010; Allen et al. 2012). Pozzo et al. (2003) speculated that most of the molecular material shielded the low mass stars from losing their disks via ionizing radiation from the OB stars and that the material has only recently been removed. Additionally, rotation periods have been obtained for 475 pre-main sequence stars in Cep OB3b (Littlefair et al. 2010) finding that the low-mass stars are rotating much more slowly compared to stars in NGC 2362 that is a similar age. This may be a potential link between star-forming environment and rotation properties calling into question models of stellar angular momentum evolution in young star clusters (Littlefair et al. 2010).

Gaia DR2 data measured the parallaxes with a clear peak at a distance of 819 ± 16 pc in K19 in agreement with the Gaia DR2 distance measured in Kuhn et al. (2019). The Gaia distance resolves an inconsistency in the distance estimates and places the cluster at the upper end of the range of previous estimates.

2 The Sizes and Structures of the Cep OB3b Sub-Clusters

In total there are ~ 3000 members of Cep OB3b, consisting of primarily low-mass ($< 1 M_{\odot}$) stars (Allen et al. 2012). The entire population of identified young stars is found in a $\sim 7 \text{ pc} \times 10 \text{ pc}$ region, and the young stars are concentrated in the east and west sub-clusters surrounded by an extended halo of these objects (Allen et al. 2012). The east sub-cluster has $\sim 2.5\times$ more pre-main sequence stars than the west and the disk fractions are different in the two sub-clusters: 32% for the east and 50% for the west (Allen et al. 2012). The difference of disk fractions is attributed to the difference in the ages of the sub-clusters, with the east being older.

In K19, we constrained the sizes, structures, and densities of the sub-clusters (see Table 1) using the analytic model developed by King (1962) for globular clusters. The central coordinates of the sub-clusters were adopted from the method of Gutermuth et al. (2009) that finds local surface density enhancements. The King model is not appropriate for the elongated and irregular structure of more deeply embedded clusters such as the ONC (Gutermuth et al. 2009; Kuhn et al. 2014; Megeath et al. 2016), but

the more circular symmetry of the two Cep OB3b sub-clusters motivates the use of this model. The *Spitzer* and *Chandra* data were used for the King model fits parameterized by a core radius, an outer radius, and a central peak density (see Figure 2). The core radii are 1.4 pc (east) and 0.5 pc (west) with outer radii of 2.32 pc (east) and 3.1 pc (west). K19 found the west deviates significantly from circular symmetry and it is significantly elongated. In comparison, the east appears circularly symmetric with a relatively smooth distribution of stars, is richer in members than the west and has a larger core radius. The east also has the lone O star in the cluster vs the west that has several B stars scattered throughout. The west is characterized by elongation, a core radius that is less than half of that for the east, and has fewer members. These properties support the idea that the east has undergone expansion due to gas dispersal in contrast to the west, which is more compact. Cep OB3b is comparable in size and membership to the ONC (Carpenter et al. 2000 & Allen et al. 2007). The peak densities can be compared to the ONC. Both sub-clusters have peak densities that are much lower than in the ONC (Hillenbrand et al. 1998 & Megeath et al. 2016) suggesting they have undergone expansion.

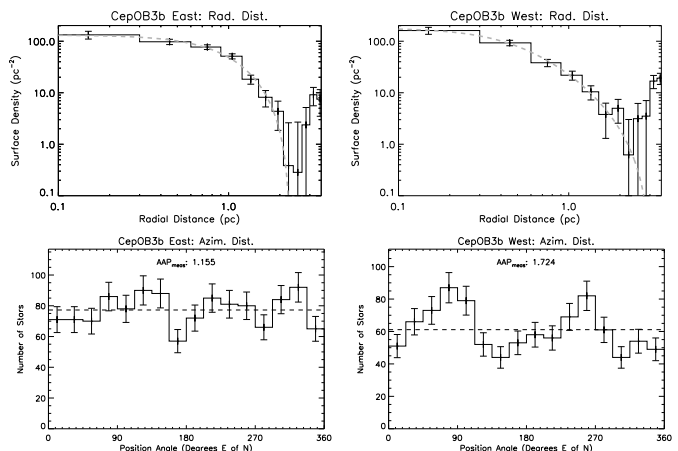


Figure 2: Radial and azimuthal distributions of the Cep OB3b sub-clusters. The top left and right plots are the surface density vs. radial distance for the east and west sub-clusters, respectively. The bottom left and right plots are the number of stars vs. position angle for the east and west sub-clusters, respectively. The solid lines show the fits to the King (1962) model. The azimuthal asymmetric parameter (AAP) measures the deviation from circular symmetry (Gutermuth et al. 2005).

3 An RV Survey of Cep OB3b

K19 carried out a radial velocity (RV) survey of the two sub-clusters using Hectoschelle on the Multi Mirror Telescope on Mount Hopkins, AZ. Hectoschelle is a fiber-fed echelle spectrograph with resolving power of $\sim 32,000$. A total of 561 spectra over five epochs were taken of 499 distinct stars, 190 of which were identified as members (Figure 3). Sources showing signatures of multiplicity were removed from the analysis, as stars in a binary or multiple will have RV motions measured due to the orbital motions of the system instead of the kinetic energy of the cluster itself. The average RV of the sub-clusters are similar, $-12.09 \pm 0.56 \text{ km s}^{-1}$ for the east and $-10.86 \pm 0.54 \text{ km s}^{-1}$ for the west.

To constrain the velocity dispersions of the sub-clusters, a Bayesian parameter estimation was implemented for each sub-cluster (K19) using a Monte-Carlo likelihood function comparison. Unresolved binaries were accounted for adopting the approach of Cottaar et al. (2012) to add the effect of orbital motions. Three binary fractions were tested to probe the effect of binary fraction on the resulting dispersion: 0, 0.5, and 1.0 as seen in Figure 4.

Accounting for unresolved binaries is an important step when probing an accurate kinematical survey of young clusters, since for all but the youngest, most compact clusters, the motions of the binaries dominate the observed velocity dispersion. This is due to the effect of the gas mass on the cluster motions. As the gas is dispersed and the cluster expands, binaries will begin to dominate the observed distribution if the cluster remains near virial equilibrium while expanding.

3.1 The Kinetic and Potential Energies of the Sub-Clusters

The probability distribution functions (PDF) (Figure 4) of the sub-cluster velocity dispersions were adopted to derive the kinetic energies of the sub-clusters. Here we assumed a symmetric three dimensional velocity dispersion with the values for the two directions in the plane of the sky equal to that in the radial direction. These are combined with potential energy (PE) derived from the King models to determine a final PDF, which is close to the expected fraction, of $\log(T/|U|)$ (Figure 5). Adopting a binary fraction of 0.5 in the east, $\log(T/|U|)$ has a mean value at 0.3 and a value at the peak of the distribution of 0.6. This implies that the east sub-cluster is unbound and in a state of expansion, which is consistent with the proper motion analysis of Kuhn et al. (2019). If no stars are binaries then $\log(T/|U|) > 0$, also implying an unbound, expanding state. With all the stars being binaries the mean value is in a subvirial, bound state with a probability of 61% of

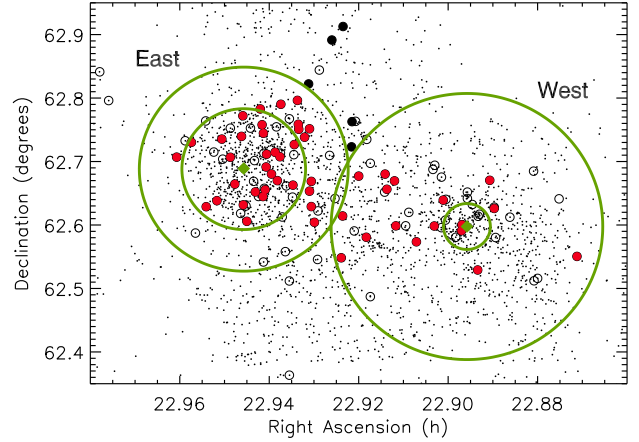


Figure 3: Spatial distribution of all the members of Cep OB3b with the core and outer radii (green circles) overlaid. The black points are the all the members of Cep OB3b (Allen et al. 2012) and the open circles have Hectoschelle spectra. The filled black circles are members with Hectoschelle spectra but fall outside the outer radii. The filled red circles are members with Hectoschelle spectra within the outer radii and are used for the kinematic analysis in K19. The green diamonds are the centers of the respective sub-clusters.

being bound. For the west sub-cluster, adopting a binary fraction of 0.5, results in a mean of $\log(T/|U|) \sim -0.16$ with a large range of outcomes and a mode of 0.3. The mean value falls into an approximate virial state while there is a 55% chance of an unbound state. The binary fraction of 0.5 was adopted as the most likely value due to Raghavan et al. (2010) determining that solar-type stars have a binary fraction of 0.44.

It is important to recall that not all of the gas mass has been expelled from Cep OB3b even though it is currently in the gas dispersal phase. Gas remains in both sub-clusters (see Allen et al. 2012, Figure 4). The amount of gas mass in the sub-clusters based on the 2MASS extinction map resulted in $\sim 136 M_{\odot}$ and $\sim 697 M_{\odot}$ in the east and west, respectively (K19). The gas measured in the east is located near the edge of the sub-cluster and is not centrally concentrated. In contrast, the gas mass in the west is concentrated inside the core radius. The mass in the west is dominated by the gas, up to 77%, and because it is centrally concentrated it is necessary to include the gas mass in the potential energy. Accounting for the gas mass, the $\log(T/|U|)$ values drop by ~ 0.4 resulting in a subvirial, bound state, which is adopted as the more accurate kinematical result in K19.

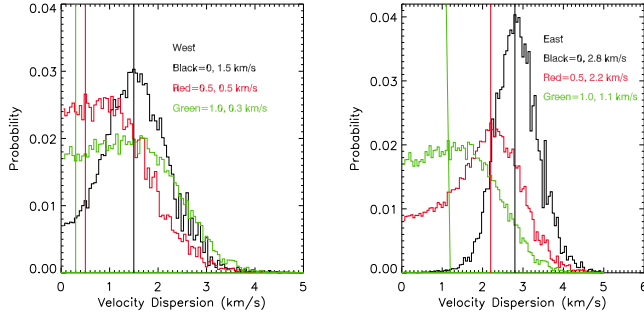


Figure 4: The PDF of the velocity distributions in the west and east. Black is for a binary fraction of 0, red for 0.5, and green is 1.0, with peak velocity dispersion values are 2.8/1.5, 2.2/0.5, and 1.1/0.3 km s^{-1} , for the east/west, respectively.

4 The Fate of Cepheus OB3b

4.1 The East Sub-Cluster

There is clear evidence that the east sub-cluster has undergone gas expulsion due to the radiation and winds of the O7V star. Simulations of clusters after gas dispersal predict that clusters expand significantly, with the ratio of the final to initial radii equal to the ratio of the initial to final stellar mass in the case the cluster remains bound (Baumgardt & Kroupa 2007; Moeckel & Bate 2010). Although the cluster as a whole may be unbound, with the kinetic energy exceeding the potential part, a fraction of the stars may remain bound (Adams 2000; Baumgardt & Kroupa 2007). A comparison of the size and density of the east to younger clusters indicates that this sub-cluster is currently undergoing expansion. Indirect evidence for the expansion of the east sub-cluster is the low peak stellar density, the large core radius, and the circular symmetry, all of which are different than the properties of young clusters still embedded in their natal clouds. Direct evidence is found in the proper motions of Kuhn et al. (2019) and the RV data shows it is unbound. K19 looked at the virial ratio, $Q = T/|U|$, and used the model simulations from Farias et al. (2018) to estimate the fraction of stars that remain bound after gas dispersal. For a binary fraction of 0.5 and an expectation value of $\log(T/|U|)$ of 0.3, $\sim 35\%$ or 300 stars are predicted to remain bound in the east sub-cluster.

4.2 The West Sub-Cluster

The west sub-cluster remains more embedded than the east. Additional evidence that it is not as dynamically

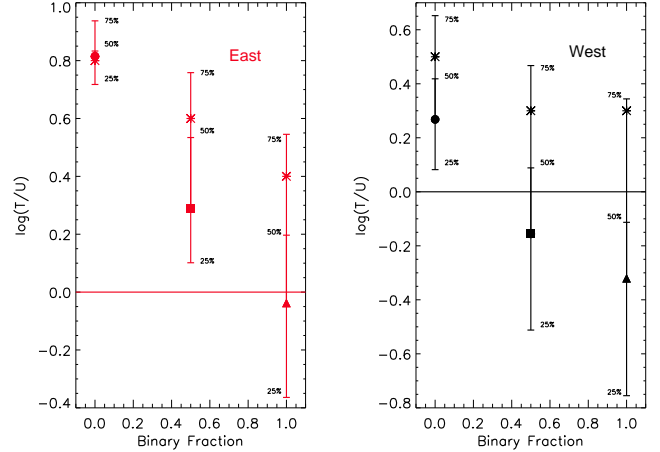


Figure 5: Plot of $\log(T/|U|)$ for both sub-clusters as a function of adopted binary fraction. The east is represented in red (left) and the west in black (right). The horizontal line indicates $\log(T/|U|)=0$ and is the dividing line between a bound and unbound cluster. The circles, squares, and triangles are the mean value for each distribution and the overlaid asterisks are the values at the peaks of the distribution in Figure 4.

evolved as the east sub-cluster is its elongated morphology and smaller core size. The lesser degree of dynamical evolution does not necessarily imply a younger age. The west contains one B3 and three B5 stars that do not have the UV radiation of the O7 star in the east sub-cluster to clear natal gas as quickly, which may allow a significant amount of the gas to remain. As the west sub-cluster evolves it is unclear how quickly the remaining natal gas will disperse and how the virial ratio will change as a result. It is a reasonable assumption that $T/|U|$ will decrease as it expands, but by how much remains unclear. The range of $\log(T/|U|)$ values in Figure 5 are consistent with a cluster that is currently virialized, although with large error bars. Using the model simulations from Farias et al. (2018) again, K19 find that $\sim 75\%$ of the cluster, or ~ 300 stars, will remain bound when adopting a binary fraction of 0.5 and an expectation value of $\log(T/|U|)$ of -0.16. We expect that a large fraction of the stars will form a bound cluster. For example, Baumgardt & Kroupa (2007) found that a combination of very slow gas expulsion and a very weak external tidal field with an initial star formation efficiency of 33% can produce a bound cluster with 90% of stars remaining bound.

4.3 A Double Cluster?

The Gaia DR2 catalog was cross matched with Cep OB3b members with youth indicators using their 2MASS IDs, to determine the proper motion of both sub-clusters and a distance to Cep OB3b (K19). The total cluster has proper motion components of 0.69 ± 0.02 (μ_α^*) and -2.44 ± 0.02 (μ_δ) mas yr⁻¹; this translates to a difference of ~ 2 km s⁻¹ of the sub-clusters. The sub-clusters are moving away from each other and will continue to increase in separation. The anticipated result will be the formation of two bound clusters of ~ 300 stars each. This seems exceptional in the light that $\sim 7\%$ of embedded clusters form open clusters (Lada & Lada 2003). This might be due to unusual environmental conditions in the Cep OB3b cluster. Alternatively, there might be other factors that contribute to the dissipation of clusters and the two sub-clusters will, in the end, disperse. For example, additional dynamical effects come into play in simulations when binaries and a realistic range of masses are used (Moeckel et al. 2012). Finally, the tidal forces between the sub-clusters, and between the sub-clusters and molecular clouds may disrupt the clusters or strip members. It should also be noted that the large uncertainties in the velocity dispersions translate into large uncertainties in the dynamical outcomes in K19.

If both sub-clusters do in fact form bound clusters as predicted by some simulations, Cep OB3b will become a rare double cluster, with each cluster drifting away in time. It will also be a rare laboratory for establishing the conditions and environmental factors that produce bound clusters.

Future spectroscopic RV data of higher resolution can probe the differences between the east and west sub-clusters and aid in a better understanding of the age and initial mass function of Cep OB3b. The rich data set of Cep OB3b continues to grow and its comparable size with the ONC, but during disk dissipation and gas dispersal, increases our understanding of cluster evolution. Further observations with Gaia and other telescopes will provide more detailed studies of Cep OB3b in addition to other cluster regions to understand the evolution of young clusters from formation to dispersal.

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Table 1: Main Parameters of Cep OB3b in K19

Parameter	East	West
# of Members	~ 800	~ 450
A (pc ⁻²)	541 ± 202	258 ± 42
R _{core} (pc)	1.36 ± 0.30	0.52 ± 0.11
R _{outer} (pc)	2.32 ± 0.19	3.1 ± 1.0
AAP _{meas}	1.155	1.724
Gas Mass (M _⊙)	136	697
RV (km s ⁻¹)	-12.09 ± 0.563	-10.86 ± 0.538
Velocity Dispersion (km s ⁻¹)	$1.9^{+0.5}_{-0.4}$	$1.10^{+0.30}_{-0.44}$
log(T/U)	0.3	-0.16

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First grids of low-mass stellar models and isochrones with self-consistent treatment of rotation : From 0.2 to 1.5 M_{\odot} at 7 metallicities from PMS to TAMS

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We present an extended grid of state-of-the art stellar models for low-mass stars including updated physics (nuclear reaction rates, surface boundary condition, mass-loss rate, angular momentum transport, torque and rotation-induced mixing prescriptions). We aim at evaluating the impact of wind braking, realistic atmospheric treatment, rotation and rotation-induced mixing on the structural and rotational evolution from the pre-main sequence to the turn-off. Using the STAREVOL code, we provide an updated PMS grid. We compute stellar models for 7 different metallicities, from $[\text{Fe}/\text{H}] = -1$ dex to $[\text{Fe}/\text{H}] = +0.3$ dex with a solar composition corresponding to $Z=0.0134$. The initial stellar mass ranges from 0.2 to 1.5 M_{\odot} with extra grid refinement around one solar mass. We also provide rotating models for three different initial rotation rates (slow, median and fast) with prescriptions for the wind braking and disc-coupling timescale calibrated on observed properties of young open clusters. The rotational mixing includes an up-to-date description of the turbulence anisotropy in stably stratified regions. The overall behaviour of our models at solar metallicity – and its constitutive physics – is validated through a detailed comparison with a variety of distributed evolutionary tracks. The main differences arise from the choice of surface boundary conditions and initial solar composition. The models including rotation with our prescription for angular momentum extraction and self-consistent formalism for angular momentum transport are able to reproduce the rotation period distribution observed in young open clusters over a broad mass-range. These models are publicly available and may be used to analyse data coming from present and forthcoming asteroseismic and spectroscopic surveys such as Gaia, TESS and PLATO.

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Planet-forming material in a protoplanetary disc: the interplay between chemical evolution and pebble drift

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The composition of gas and solids in protoplanetary discs sets the composition of planets that form out of them. Recent chemical models have shown that the composition of gas and dust in discs evolves on Myr time-scales, with volatile species disappearing from the gas phase. However, discs evolve due to gas accretion and radial drift of dust on time-scales similar to these chemical time-scales. Here we present the first model coupling the chemical evolution in the disc mid-planes with the evolution of discs due to accretion and radial drift of dust. Our models show that transport will always overcome the depletion of CO_2 from the gas phase, and can also overcome the depletion of CO and CH_4 unless both transport is slow (viscous $\alpha \lesssim 10^{-3}$) and the ionization rate is high ($\zeta \approx 10^{-17}$). Including

radial drift further enhances the abundances of volatile species because they are carried in on the surface of grains before evaporating left at their ice lines. Due to large differences in the abundances within 10 au for models with and without efficient radial drift, we argue that composition can be used to constrain models of planet formation via pebble accretion.

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IRAS 23385+6053: An embedded massive cluster in the making

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This study is part of the CORE project, an IRAM/NOEMA large program consisting of observations of the millimeter continuum and molecular line emission towards 20 selected high-mass star-forming regions. The goal of the program is to search for circumstellar accretion disks, study the fragmentation process of molecular clumps, and investigate the chemical composition of the gas in these regions. We focus on IRAS 23385+6053, which is believed to be the least-evolved source of the CORE sample. This object is characterized by a compact molecular clump that is IR-dark shortward of 24 μm and is surrounded by a stellar cluster detected in the near-IR. Our aim is to study the structure and velocity field of the clump. Observations were performed at ~ 1.4 mm and employed three configurations of NOEMA and additional single-dish maps, merged with the interferometric data to recover the extended emission. Our correlator setup covered a number of lines from well-known hot core tracers and a few outflow tracers. The angular (~ 0.45 – 0.9 arcsec) and spectral (0.5 km/sec) resolutions were sufficient to resolve the clump in IRAS 23385+6053 and investigate the existence of large-scale motions due to rotation, infall, or expansion. We find that the clump splits into six distinct cores when observed at sub-arcsecond resolution. These are identified through their 1.4 mm continuum and molecular line emission. We produce maps of the velocity, line width, and rotational temperature from the methanol and methyl cyanide lines, which allow us to investigate the cores and reveal a velocity and temperature gradient in the most massive core. We also find evidence of a bipolar outflow, possibly powered by a low-mass star. We present the tentative detection of a circumstellar self-gravitating disk lying in the most massive core and powering a large-scale outflow previously known in the literature. In our scenario, the star powering the flow is responsible for most of the luminosity of IRAS 23385+6053 ($\sim 3000 L_{\odot}$). The other cores, albeit with masses below the corresponding virial masses, appear to be accreting material from their molecular surroundings and are possibly collapsing or on the verge of collapse. We conclude that we are observing a sample of star-forming cores that is bound to turn into a cluster of

massive stars.

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Emerging trends in metallicity and lithium properties of debris disc stars

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Dwarf stars with debris discs and planets appear to be excellent laboratories to study the core accretion theory of planets formation. These systems are however, insufficiently studied. In this paper we present the main metallicity and lithium abundance properties of these stars together with stars with only debris discs and stars with only planets. Stars without detected planets nor discs are also considered. The analysed sample is formed by main-sequence FGK field single stars. Apart from the basic stellar parameters, we include the use of dusty discs masses. The main results show for the first time that the dust mass of debris disc stars with planets correlate with metallicity. We confirm that these disc dust masses are related to their central stellar masses.

Separately, the masses of stars and those of planets also correlate with metallicity. We conclude that two conditions are necessary to form giant planets: to have a sufficient metallicity and also a sufficient protoplanetary mass of gas and dust. The debris discs masses of stars without giant planets do not correlate with metallicity, because they do not fulfil these two conditions. Concerning lithium, by adopting a stellar model for lithium depletion based on a strong interaction between the star and a protoplanetary disc, we found that in agreement with the model predictions, observations indicate that the main lithium depletion occurs during this initial protoplanetary evolution stage. We show that the ultimately lithium depletion is independent of the presence or absence of planets and appears to be only age dependent.

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Evidence for a circumplanetary disc around protoplanet PDS 70 b

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We present the first observational evidence for a circumplanetary disc around the protoplanet PDS 70 b, based on a new spectrum in the *K* band acquired with VLT/SINFONI. We tested three hypotheses to explain the spectrum: Atmospheric emission from the planet with either (1) a single value of extinction or (2) variable extinction, and (3) a combined atmospheric and circumplanetary disc model. Goodness-of-fit indicators favour the third option, suggesting circumplanetary material contributing excess thermal emission — most prominent at $\lambda \gtrsim 2.3 \mu\text{m}$. Inferred accretion rates ($\sim 10^{-7.8} - 10^{-7.3} M_J \text{ yr}^{-1}$) are compatible with observational constraints based on the H α and Br γ lines. For the planet, we derive an effective temperature of 1500–1600 K, surface gravity $\log(g) \sim 4.0$, radius $\sim 1.6 R_J$, mass

$\sim 10 M_J$, and possible thick clouds. Models with variable extinction lead to slightly worse fits. However, the amplitude ($\Delta A_V \gtrsim 3$ mag) and timescale of variation (\lesssim years) required for the extinction would also suggest circumplanetary material.

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Separating extended disc features from the protoplanet in PDS 70 using VLT/SINFONI

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Transition discs are prime targets to look for protoplanets and study planet-disc interactions. We present VLT/SINFONI observations of PDS 70, a transition disc with a recently claimed embedded protoplanet. We take advantage of the angular and spectral diversity present in our data for an optimal PSF modeling and subtraction using principal component analysis (PCA). We report the redetection of PDS 70 b, both the front and far side of the outer disc edge, and the detection of several extended features in the annular gap. We compare spectral differential imaging applied before (PCA-SADI), and after (PCA-ASDI) angular differential imaging. Our tests suggest that PCA-SADI better recovers extended features, while PCA-ASDI is more sensitive to point sources. We adapted the negative fake companion (NEGFC) technique to infer the astrometry of the companion, and derived $r = 193.5 \pm 4.9$ mas and $PA = 158.7 \pm 3.0$ deg. We used both NEGFC and ANDROMEDA to infer the K -band spectro-photometry of the protoplanet, and found results consistent with recent VLT/SPHERE observations, except for their 2018/02 epoch measurement in the $K2$ filter. Finally, we derived an upper limit of $\dot{M}_b < 1.26 \times 10^{-7} [\frac{5 M_{Jup}}{M_b}] [\frac{R_b}{R_{Jup}}] M_{Jup} \text{ yr}^{-1}$ for the accretion rate of the companion based on an adaptation of PCA-SADI/PCA-ASDI around the Br γ line.

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Time variability in the bipolar scattered light nebula of L1527 IRS: A possible warped inner disk

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Context. The bipolar outflows associated with low-mass protostars create cavities in the infalling envelope. These cavities are illuminated by the central protostar and inner disk, creating a bipolar scattered light nebula at near-infrared and mid-infrared wavelengths. The variability of the scattered light nebula in both total intensity and intensity as a function of position in the scattered light nebula can provide important insights into the structure of the inner

disk that cannot be spatially resolved. **Aims.** We aim to determine the likelihood that a warped inner disk is the origin of the surface brightness variability in the bipolar scattered light nebula associated with L1527 IRS. **Methods.** We present results from near-IR imaging conducted over the course of seven years, with periods of monthly cadence monitoring. We used Monte Carlo radiative transfer models to interpret the observations. **Results.** We find a time varying, asymmetrical brightness in the scattered light nebulae within the outflow cavities of the protostar. Starting in 2007, the surface brightnesses of the eastern and western outflow cavities were roughly symmetric. Then, in 2009, the surface brightnesses of the cavities were found to be asymmetric, with a substantial increase in surface brightness and a larger increase in the eastern outflow cavity. More regular monitoring was conducted from 2011 to 2014, revealing a rotating pattern of surface brightness variability in addition to a slow change of the eastern and western outflow cavities toward symmetry, but still not as symmetric as observed in 2007. We find that an inner disk warp is a feasible mechanism to produce the rotating pattern of surface brightness variability.

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ALMA reveals the magnetic field evolution in the high-mass star forming complex G9.62+0.19

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Context. The role of magnetic fields during the formation of high-mass stars is not yet fully understood, and the processes related to the early fragmentation and collapse are largely unexplored today. The high-mass star forming region G9.62+0.19 is a well known source, presenting several cores at different evolutionary stages.

Aims. We determine the magnetic field morphology and strength in the high-mass star forming region G9.62+0.19, to investigate its relation to the evolutionary sequence of the cores.

Methods. We use Band 7 ALMA observations in full polarisation mode and we analyse the polarised dust emission. We estimate the magnetic field strength via the Davis-Chandrasekhar-Fermi and the Structure Function methods.

Results. We resolve several protostellar cores embedded in a bright and dusty filamentary structure. The polarised emission is clearly detected in six regions. Moreover the magnetic field is oriented along the filament and appears perpendicular to the direction of the outflows. We suggest an evolutionary sequence of the magnetic field, and the less evolved hot core exhibits a magnetic field stronger than the more evolved one. We detect linear polarisation from thermal line emission and we tentatively compared linear polarisation vectors from our observations with previous linearly polarised OH masers observations. We also compute the spectral index, the column density and the mass for some of the cores.

Conclusions. The high magnetic field strength and the smooth polarised emission indicate that the magnetic field could play an important role for the fragmentation and the collapse process in the star forming region G9.62+0.19 and that the evolution of the cores can be magnetically regulated. On average, the magnetic field derived by the linear polarised emission from dust, thermal lines and masers is pointing in the same direction and has consistent strength.

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Interaction between Northern Coal Sack in the Cyg OB 7 cloud complex and the multiple super nova remnants including HB 21

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We report possible interaction between multiple super nova remnants (SNRs) and Northern Coal Sack (NCS) which is a massive clump ($\sim 1000 M_{\odot}$) in the Cyg OB 7 cloud complex and is forming a massive Class 0 object. We performed molecular observations of the $^{12}\text{CO}(J=1-0)$, $^{13}\text{CO}(J=1-0)$, and $\text{C}^{18}\text{O}(J=1-0)$ emission lines using the 45m telescope at the Nobeyama Radio Observatory, and we found that there are mainly four velocity components at $V_{\text{LSR}} \simeq -20, -6, -4$, and 10 kms. The -6 and -4 kms components correspond to the systemic velocities of NCS and the Cygnus OB 7 complex, respectively, and the other velocity components originate from distinct smaller clouds. Interestingly, there are apparent correlations and anti-correlations among the spatial distributions of the four components, suggesting that they are physically interacting with one another. On a larger scale, we find that a group of small clouds belonging to the -20 and 10 kms components are located along two different arcs around some SNRs including HB 21 which has been suggested to be interacting with the Cyg OB 7 cloud complex, and we also find that NCS is located right at the interface of the arcs. The small clouds are likely to be the gas swept up by the stellar wind of the massive stars which created the SNRs. We suggest that the small clouds aligned along the two arcs recently encountered NCS and the massive star formation in NCS was triggered by the strong interaction with the small clouds.

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Cloud-cloud collision in the DR 21 cloud as a trigger of massive star formation

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We report on a possible cloud-cloud collision in the DR 21 region, which we found through molecular observations with the Nobeyama 45-m telescope. We mapped an area of $\sim 8 \text{ arcmin} \times 12 \text{ arcmin}$ around the region with twenty molecular lines including the $^{12}\text{CO}(J=1-0)$ and $^{13}\text{CO}(J=1-0)$ emission lines, and sixteen of them were significantly detected. Based on the ^{12}CO and ^{13}CO data, we found five distinct velocity components in the observed region, and we call molecular gas associated with these components “ -42 ”, “ -22 ”, “ -3 ”, “ 9 ”, and “ 17 ” km s^{-1} clouds taking after their typical radial velocities. The -3 km s^{-1} cloud is the main filamentary cloud ($\sim 31,000 M_{\odot}$) associated with young massive stars such as DR21 and DR21(OH), and the 9 km s^{-1} cloud is a smaller cloud ($\sim 3,400 M_{\odot}$) which may be an extension of the W75 region in the north. The other clouds are much smaller. We found a clear anticorrelation in the distributions of the -3 and 9 km s^{-1} clouds, and detected faint ^{12}CO emission having intermediate velocities bridging the two clouds at their intersection. These facts strongly indicate that the two clouds are colliding against each other. In addition, we found that DR21 and DR21(OH) are located in the periphery of the densest part of the 9 km s^{-1} cloud, which is consistent with results of recent numerical simulations of cloud-cloud collisions. We therefore suggest that the -3 and 9 km s^{-1} clouds are colliding, and that the collision induced the massive star formation in the DR21 cloud. The interaction of the -3 and 9 km s^{-1} clouds was previously suggested by Dickel et al. (1978), and our results strongly support their hypothesis of the interaction.

Discovery of CCS Velocity-Coherent Substructures in the Taurus Molecular Cloud 1

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We present the results of mapping observations toward a nearby starless filamentary cloud, the Taurus Molecular Cloud 1 (TMC-1), in the CCS($J_N = 4_3 - 3_2$, 45.379033 GHz) emission line, using the Nobeyama 45-m telescope. The map shows that the TMC-1 filament has a diameter of ~ 0.1 pc and a length of ~ 0.5 pc at a distance of 140 pc. The position-velocity diagrams of CCS clearly indicate the existence of velocity-coherent substructures in the filament. We identify 21 substructures that are coherent in the position-position-velocity space by eye. Most of the substructures are elongated along the major axis of the TMC-1 filament. The line densities of the subfilaments are close to the critical line density for the equilibrium ($\sim 17 M_\odot \text{ pc}^{-1}$ for the excitation temperature of 10 K), suggesting that self-gravity should play an important role in the dynamics of the subfilaments.

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Revealing the Star-Disk-Jet Connection in GM Aur using Multiwavelength Variability

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Here we analyze the first simultaneous X-ray, ultraviolet, optical, infrared, and centimeter observations of a T Tauri star (TTS). We present three epochs of simultaneous *Spitzer* and VLA data of GM Aur separated by ~ 1 wk. These data are compared to previously published *HST* and *Chandra* observations from which mass accretion rates (\dot{M}) and X-ray luminosities, respectively, were measured. The mid-infrared emission increases along with \dot{M} , and we conclude that this is due to an increase in the mass in the inner disk. The cm emission, which probes the jet, also appears to increase as \dot{M} increases, and the changes in the cm flux are consistent with the variability in \dot{M} assuming the mass-loss rate is $\sim 10\% \dot{M}$. The 3 cm emission morphology also appears changed compared with observations taken three years previously, suggesting that for the first time, we may be tracking changes in the jet morphology of a TTS. The X-ray luminosity is constant throughout the three epochs, ruling out variable high-energy stellar radiation as the cause for the increases in the mid-infrared or cm emission. Tying together the multiwavelength variability observed, we conclude that an increase in the surface density in the inner disk resulted in more mass loading onto the star and therefore a higher \dot{M} , which led to a higher mass-loss rate in the jet. These results stress the importance of coordinated multiwavelength work to better understand the star-disk-jet connection.

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Analysis and test of the central-blue-spot infall hallmark

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The infall of material onto a protostar, in the case of optically thick line emission, produces an asymmetry in the blue- and red-wing line emissions. For an angularly resolved emission, this translates in a blue central spot in the first-order moment (intensity weighted velocity) map. An analytical expression for the first-order moment intensity as a function of the projected distance was derived, for the cases of infinite and finite infall radius. The effect of a finite angular resolution, which requires the numerical convolution with the beam, was also studied. This method was applied to existing data of several star-forming regions, namely G31.41+0.31 HMC, B335, and LDN 1287, obtaining good fits to the first-order moment intensity maps, and deriving values of the central masses onto which the infall is taking place (G31.41+0.31 HMC: 70–120 M_{\odot} ; B335: 0.1 M_{\odot} ; Guitar Core of LDN 1287: 4.8 M_{\odot}). The central-blue-spot infall hallmark appears to be a robust and reliable indicator of infall.

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High gas/dust size ratio indicating efficient radial drift in the mm-faint CX Tau disk

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The large majority of protoplanetary disks have very compact continuum emission ($\lesssim 15$ AU) at millimeter wavelengths. However, high angular resolution observations that resolve these small disks are still lacking, due to their intrinsically fainter emission compared with large bright disks. In this letter we present 1.3 mm ALMA data of the faint disk (~ 10 mJy) orbiting the TTauri star CX Tau at a resolution of ~ 40 mas, ~ 5 AU in diameter. The millimeter dust disk is compact, with a 68% enclosing flux radius of 14 AU, and the intensity profile exhibits a sharp drop between 10 and 20 AU, and a shallow tail between 20 and 40 AU. No clear signatures of substructure in the dust continuum are observed, down to the same sensitivity level of the DSHARP large program. However, the angular resolution does not allow us to detect substructures on the scale of the disk aspect ratio in the inner regions. The radial intensity profile closely resembles the inner regions of more extended disks imaged at the same resolution in DSHARP, but with no rings present in the outer disk. No inner cavity is detected, even though the disk has been classified as a transition disk from the spectral energy distribution in the near-infrared. The emission of ^{12}CO is much more extended, with a 68% enclosing flux radius of 75 AU. The large difference of the millimeter dust and gas extents (> 5) strongly points to radial drift, and closely matches the predictions of theoretical models.

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Runaways and shells around the CMa OB1 association

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The origin of the arc-shaped Sh 2-296 nebula is still unclear. Mainly due to its morphology, the nebula has been suggested to be a 0.5 Myr-old supernova remnant (SNR) that could be inducing star formation in the CMa OB1 association. Therefore, this region can be an excellent laboratory for the investigation of the influence of massive stars on their surroundings. We aim to show, for the first time, that the nebula is part of a large, shell-like structure, which we have designated the “CMa shell”, enclosing a bubble created by successive supernova (SN) explosions. We identified three runaway stars, associated with bow-shock structures, in the direction of the CMa shell and we investigate the possibility that they have originated in the center of the shell. By analyzing images of the CMa OB1 association at several wavelengths, we clearly see that the Sh 2-296 nebula is in fact part of a large structure, which can be approximated by a large (with a diameter of ~ 60 pc) elliptical shell. Using the recent *Gaia-DR2* astrometric data, we trace back the path of the three runaway stars, in order to find their original position in the past, with relation to the CMa shell. We also revise the heating and ionization of the Sh 2-296 nebula, by comparing the photon budget provided by the O stars in the region with results from radio observations. We find that the runaway stars have likely been ejected from a Trapezium-like progenitor cluster on three successive SN explosions having taken place ~ 6 , ~ 2 and ~ 1 Myr ago. We also show that the few late-type O stars in the region cannot explain the ionization of the Sh 2-296 nebula and other mechanisms need to be at work. We argue that, though we now have evidence for several SNe events in the CMa OB1 association, the SNe probably played a minor role in triggering star formation in these clouds. In contrast, the CMa OB1 association, as it is now, likely testifies to the last stages of a star-forming region.

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The Astrochemical Impact of Cosmic Rays in Protoclusters I: Molecular Cloud Chemistry

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We present astrochemical photo-dissociation region models in which cosmic ray attenuation has been fully coupled to the chemical evolution of the gas. We model the astrochemical impact of cosmic rays, including those accelerated by protostellar accretion shocks, on molecular clouds hosting protoclusters. Our models with embedded protostars reproduce observed ionization rates. We study the imprint of cosmic ray attenuation on ions for models with different surface cosmic ray spectra and different star formation efficiencies. We find that abundances, particularly ions, are sensitive to the treatment of cosmic rays. We show the column densities of ions are under predicted by the ‘classic’ treatment of cosmic rays by an order of magnitude. We also test two common chemistry approximations used to infer ionization rates. We conclude that the approximation based on the H_3^+ abundance under predicts the ionization rate except in regions where the cosmic rays dominate the chemistry. Our models suggest the chemistry in dense gas will be significantly impacted by the increased ionization rates, leading to a reduction in molecules such as NH_3 and causing H_2 -rich gas to become [C II] bright.

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Star-planet tidal interaction and the limits of gyrochronology

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Age estimation techniques such as gyrochronology and magnetochronology cannot be applied to stars that have exchanged angular momentum with their close environments. This is especially true for a massive close-in planetary companion (with a period of a few days or less) that could have been strongly impacted by the rotational evolution of

the host star, throughout the stellar evolution, through the star-planet tidal interaction.

We show that the interaction of a close-in massive planet with its host star can strongly modify the surface rotation rate of this latter, in most of the cases associated with a planetary engulfment. In such cases, a gyrochronology analysis of the star would incorrectly make it appear as rejuvenated, thus preventing us from using this method with confidence. To try overcome this issue, we proposed the proof of concept of a new age determination technique that we call the tidal-chronology method, which is based on the observed pair $P_{\text{rot},\star}$ - P_{orb} of a given star-planet system.

The gyrochronology technique can only be applied to isolated stars or star-planet systems outside a specific range of $P_{\text{rot},\star}$ - P_{orb} . This region tends to expand for increasing stellar and planetary mass. In that forbidden region, or if any planetary engulfment is suspected, gyrochronology should be used with extreme caution, while tidal-chronology could be considered. This technique does not provide a precise age for the system yet; however, it is already an extension of gyrochronology and could be helpful to determine a more precise range of possible ages for planetary systems composed of a star between 0.3 and 1.2 M_{\odot} and a planet more massive than 1 M_{jup} initially located at a few hundredths of au from the host star.

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Gaia Stellar Kinematics in the Head of the Orion A Cloud: Runaway Stellar Groups and Gravitational Infall

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This work extends previous kinematic studies of young stars in the Head of the Orion A cloud (OMC-1/2/3/4/5). It is based on large samples of infrared, optical, and X-ray selected pre-main sequence stars with reliable radial velocities and Gaia-derived parallaxes and proper motions. Stellar kinematic groups are identified assuming they mimic the motion of their parental gas. Several groups are found to have peculiar kinematics: the NGC 1977 cluster and two stellar groups in the Extended Orion Nebula (EON) cavity are caught in the act of departing their birthplaces. The abnormal motion of NGC 1977 may have been caused by a global hierarchical cloud collapse, feedback by massive Ori OB1ab stars, supersonic turbulence, cloud-cloud collision, and/or slingshot effect; the former two models are favored by us. EON groups might have inherited anomalous motions of their parental cloudlets due to small-scale ‘rocket effects’ from nearby OB stars. We also identify sparse stellar groups to the east and west of Orion A that are drifting from the central region, possibly a slowly expanding halo of the Orion Nebula Cluster. We confirm previously reported findings of varying line-of-sight distances to different parts of the cloud’s Head with associated differences in gas velocity. Three-dimensional movies of star kinematics show contraction of the groups of stars in OMC-1 and global contraction of OMC-123 stars. Overall, the Head of Orion A region exhibits complex motions consistent with theoretical models involving hierarchical gravitational collapse in (possibly turbulent) clouds with OB stellar feedback.

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Modelling the Spatial Distribution and Origin of CO Gas in Debris Disks

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The detection of gas in debris disks raises the question of whether this gas is a remnant from the primordial proto-

planetary phase, or released by the collision of secondary bodies. In this paper we analyze ALMA observations at $1''$ – $1.5''$ resolution of three debris disks where the ^{12}CO (2–1) rotational line was detected: HD131835, HD138813, and HD156623. We apply the iterative Lucy-Richardson deconvolution technique to the problem of circumstellar disks to derive disk geometries and surface brightness distributions of the gas. The derived disk parameters are used as input for thermochemical models to test both primordial and cometary scenarios for the origin of the gas. We favor a secondary origin for the gas in these disks and find that the CO gas masses ($\sim 3 \times 10^{-3} M_{\oplus}$) require production rates ($\sim 5 \times 10^{-7} M_{\oplus} \text{ yr}^{-1}$) similar to those estimated for the bona-fide gas rich debris disk β Pic.

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Dust Polarization in Four Protoplanetary Disks at 3 mm: Further Evidence of Multiple Origins

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We present polarimetric observations of four Class II protoplanetary disks (DG Tau, Haro 6-13, RY Tau, and MWC 480) taken with the Atacama Large Millimeter/submillimeter Array (ALMA) at 3 mm. The polarization morphologies observed fall into two distinct categories: azimuthal polarization (DG Tau and Haro 6-13) and polarization parallel to the disk minor axis (RY Tau and MWC 480). The mechanisms responsible for disk polarization at millimeter and submillimeter wavelengths are currently under debate. In this Letter, we investigate two mechanisms capable of producing polarized dust emission in disks: self-scattering and grain alignment to the radiation anisotropy. The polarization morphologies of DG Tau and Haro 6-13 are broadly consistent with that expected from radiation alignment (though radiative alignment still does not account for all of the features seen in these disks), while RY Tau and MWC 480 are more consistent with self-scattering. Such a variation in the polarized morphology may provide evidence of dust grain size differences between the sources.

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Gas and Dust Properties in the Chamaeleon Molecular Cloud Complex based on the Optically Thick HI

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Gas and dust properties in the Chamaeleon molecular cloud complex have been investigated with emission lines from atomic hydrogen (HI) and ^{12}CO molecule, dust optical depth at 353 GHz (τ_{353}), and J -band infrared extinction (A_J). We have found a scatter correlation between the HI integrated intensity (W_{HI}) and τ_{353} in the Chamaeleon region. The scattering has been examined in terms of possible large optical depth in HI emission (τ_{HI}) using a total column density (N_{H}) model based on τ_{353} . A nonlinear relation of τ_{353} with the ~ 1.2 power of A_J has been found in opaque regions

($A_J \gtrsim 0.3$ mag), which may indicate dust evolution effect. If we apply this nonlinear relation to the N_{H} model (i.e., $N_{\text{H}} \approx \tau_{353}^{1/1.2}$) allowing arbitrary τ_{HI} , the model curve reproduces well the $W_{\text{HI}}-\tau_{353}$ scatter correlation, suggesting optically thick HI ($\tau_{\text{HI}} \sim 1.3$) extended around the molecular clouds. Based on the correlations between the CO integrated intensity and the N_{H} model, we have then derived the CO-to- H_2 conversion factor (X_{CO}) on $\sim 1.5^\circ$ scales (corresponding to ~ 4 persec) and found spatial variations of $X_{\text{CO}} \sim (0.5-3) \times 10^{20} \text{ cm}^{-2} \text{ K}^{-1} \text{ km}^{-1} \text{ s}$ across the cloud complex, possibly depending on the radiation field inside or surrounding the molecular clouds. These gas properties found in the Chamaeleon region are discussed through a comparison with other local molecular cloud complexes.

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APEX Millimeter Observations of Methanol Emission Toward High-Mass Star-Forming Cores

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We present 247-GHz molecular line observations of methanol (CH_3OH) toward sixteen massive star-forming regions, using the APEX telescope with an angular resolution of $25''$. The sample covers a range of evolutionary states, including warm molecular cores, hot molecular cores, and ultracompact HII regions. The hot cores, all of which include UC HII regions, show rich molecular line spectra, although the strength of different species and transitions varies from source to source. In contrast, the warm cores do not show significant molecular line emission. Multiple methanol transitions are detected toward nine of the hot cores; eight of these had enough transitions to use the rotation diagram method to estimate rotational temperatures and column densities. The temperatures lie in the range 104–168 K and column densities from 3×10^{16} to $7 \times 10^{18} \text{ cm}^{-2}$. Using the average methanol line parameters, we estimate virial masses, which fall in the range from 145 to 720 M_\odot and proved to be significantly higher than the measured gas masses. We discuss possible scenarios to explain the chemical differences between hot cores and warm molecular cores. One of the observed methanol lines, 4_2-5_1A^+ at 247.228 GHz, is predicted to show class II maser emission, similar in intensity to previously reported $\text{J}_0-\text{J}_{-1}\text{E}$ masers at 157 GHz. We did not find any clear evidence for maser emission among the observed sources; however, a weak maser in this line may exist in G345.01+1.79.

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Investigating the Efficiency of Explosion Chemistry as a Source of Complex Organic Molecules in TMC-1

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Many species of complex organic molecules (COMs) have been observed in several astrophysical environments but it is not clear how they are produced, particularly in cold, quiescent regions. One process that has been proposed as a means to enhance the chemical complexity of the gas phase in such regions is the explosion of the ice mantles of dust grains. In this process, a build up of chemical energy in the ice is released, sublimating the ices and producing a short lived phase of high density, high temperature gas. The gas-grain chemical code UCLCHEM has been modified to treat

these explosions in order to model the observed abundances of COMs towards the TMC-1 region. It is found that, based on our current understanding of the explosion mechanism and chemical pathways, the inclusion of explosions in chemical models is not warranted at this time. Explosions are not shown to improve the model's match to the observed abundances of simple species in TMC-1. Further, neither the inclusion of surface diffusion chemistry, nor explosions, results in the production of COMs with observationally inferred abundances.

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Nobeyama 45-m Mapping Observations toward Orion A. II. Classification of Cloud Structures and Variation of the $^{13}\text{CO}/\text{C}^{18}\text{O}$ Abundance Ratio due to far-UV Radiation

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We present results of classification of cloud structures toward Orion A Giant Molecular Cloud based on wide-field ^{12}CO ($J = 1-0$), ^{13}CO ($J = 1-0$), and C^{18}O ($J = 1-0$) observations using the Nobeyama 45 m radio telescope. We identified 78 clouds toward Orion A applying Spectral Clustering for Interstellar Molecular Emission Segmentation (SCIMES) to the data cube of the column density of ^{13}CO . Well-known subregions such as OMC-1, OMC-2/3, OMC-4, OMC-5, NGC1977, L1641-N, and Dark lane south filament (DLSF) are naturally identified as distinct structures in Orion A. These clouds also can be classified into 3 groups: the integral-shaped filament, the southern regions of Orion A, and the other filamentary structures in the outer parts of Orion A and DLSF. These groups show differences in scaling relations between the physical properties of the clouds. We derived the abundance ratio between ^{13}CO and C^{18}O , $X_{^{13}\text{CO}}/X_{\text{C}^{18}\text{O}}$, which ranges from 5.6 to 17.4 on median over the individual clouds. The significant variation of $X_{^{13}\text{CO}}/X_{\text{C}^{18}\text{O}}$ is also seen within a cloud in both of the spatial and velocity directions and the ratio tends to be high at the edge of the cloud. The values of $X_{^{13}\text{CO}}/X_{\text{C}^{18}\text{O}}$ decrease from 17 to 10 with the median of the column densities of the clouds at the column density of $N_{\text{C}^{18}\text{O}} \gtrsim 1 \times 10^{15} \text{ cm}^{-2}$ or visual extinction of $A_V \gtrsim 3 \text{ mag}$ under strong FUV environment of $G_0 > 10^3$, whereas it is almost independent of the column density in the weak FUV radiation field. These results are explained if the selective photodissociation of C^{18}O is enhanced under strong FUV environment and it is suppressed in the dense part of the clouds.

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The Milky Way Project Second Data Release: Bubbles and Bow Shocks

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Citizen science has helped astronomers comb through large data sets to identify patterns and objects that are not easily

found through automated processes. The Milky Way Project (MWP), a citizen science initiative on the Zooniverse platform, presents internet users with infrared (IR) images from *Spitzer Space Telescope* Galactic plane surveys. MWP volunteers make classification drawings on the images to identify targeted classes of astronomical objects. We present the MWP second data release (DR2) and an updated data reduction pipeline written in Python. We aggregate ~ 3 million classifications made by MWP volunteers during the years 2012–2017 to produce the DR2 catalogue, which contains 2600 IR bubbles and 599 candidate bow-shock driving stars. The reliability of bubble identifications, as assessed by comparison to visual identifications by trained experts and scoring by a machine-learning algorithm, is found to be a significant improvement over DR1. We assess the reliability of IR bow shocks via comparison to expert identifications and the colours of candidate bow-shock driving stars in the 2MASS point-source catalogue. We hence identify highly-reliable subsets of 1394 DR2 bubbles and 453 bow-shock driving stars. Uncertainties on object coordinates and bubble size/shape parameters are included in the DR2 catalog. Compared with DR1, the DR2 bubbles catalogue provides more accurate shapes and sizes. The DR2 catalogue identifies 311 new bow shock driving star candidates, including three associated with the giant H II regions NGC 3603 and RCW 49.

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When the tale comes true: multiple populations and wide binaries in the Orion Nebula Cluster

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The high-quality OmegaCAM photometry of the 3×3 deg around the Orion Nebula Cluster (ONC) in r , and i filters by Beccari et al. (2017) revealed three well-separated pre-main sequences in the color-magnitude diagram (CMD). The objects belonging to the individual sequences are concentrated towards the center of the ONC. The authors concluded that there are two competitive scenarios: a population of unresolved binaries and triples with an exotic mass ratio distribution, or three stellar populations with different ages. We use Gaia DR2 in combination with the photometric OmegaCAM catalog to test and confirm the presence of the putative three stellar populations. We also study multiple stellar systems in the ONC for the first time using Gaia DR2. We confirm that the second and third sequence members are more centrally concentrated towards the center of the ONC. In addition we find an indication that the parallax and proper motion distributions are different among the members of the stellar sequences. The age difference among stellar populations is estimated to be 1–2 Myr. We use Gaia measurements to identify and remove as many unresolved multiple system candidates as possible. Nevertheless we are still able to recover two well-separated sequences with evidence for the third one, supporting the existence of the three stellar populations. We were able to identify a substantial number of wide binary objects (separation between 1000–3000 au). This challenges previously inferred values that suggested no wide binary stars exist in the ONC. Our inferred wide-binary fraction is $\approx 5\%$. We confirm the three populations correspond to three separated episodes of star formation. Based on this result, we conclude that star formation is not happening in a single burst in this region.

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The two magnetic components in the Herbig Ae SB2 system HD 104237

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We present longitudinal magnetic field measurements $\langle B_z \rangle$ for the Herbig Ae primary and the T Tauri secondary in the SB2 system HD 104237. These measurements were carried out using high spectral resolution observations obtained with the High Accuracy Radial velocity Planet Searcher in polarimetric mode, installed at the ESO La Silla 3.6 m telescope. In agreement with previous studies of Herbig Ae stars, the longitudinal magnetic field in the primary is rather weak, ranging from 47 to 72 G. The secondary component possesses a variable, much stronger magnetic field, up to 600 G, as expected for a magnetically active T Tauri star. We estimated the rotation period of the primary, $\text{Prot} = 4.33717 \pm 0.00316$ d ($=104 \pm 0.08$ h), from metal line equivalent width variations.

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ALMA Observations of the *rho* Ophiuchus B2 Region: I. Molecular Outflows and Their Driving Sources

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We present the results of ALMA mosaic observations of dust continuum and ^{12}CO ($J = 2 - 1$), ^{13}CO ($J = 2 - 1$) and C^{18}O ($J = 2 - 1$) molecular lines toward the *rho* Ophiuchus B2 region. The 1.3-mm dust-continuum image made from the combined 12-m and 7-m Array data reveals not only the dense cores identified by past single-dish observations, but also their detailed internal substructures. The ^{12}CO ($J = 2 - 1$) images show very complex structures of protostellar outflows. They suggest that the gigantic outflow lobes in Oph B2 are presumably driven at least by two protostars, EL 32 and EL 33. We do not detect clear high velocity components associated with the Class I protostar SST c2d J162730.9-242733 and the Flat Spectrum object SSTc2d J162721.8-242727. In addition, we find interesting striations with 15arcsec ($\text{approx } 2000$ au) separations in both the ^{12}CO and ^{13}CO channel maps. The CO striations appear to be roughly parallel to the magnetic field direction, and we speculate that the directions of the striations may follow the magnetic field in the envelope of Oph B2.

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Extremely Dense Cores Associated with Chandra Sources in Ophiuchus A: Forming Brown Dwarfs Unveiled?

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On the basis of various data such as ALMA, JVLA, Chandra, it Herschel, and it Spitzer, we confirmed that two protostellar candidates in Oph-A are bona fide protostars or proto-brown dwarfs (proto-BDs) in extremely early evolutionary stages. Both objects are barely visible across infrared (IR, i.e., near-IR to far-IR) bands. The physical nature of the cores is very similar to that expected in first hydrostatic cores (FHSCs), objects theoretically predicted in the evolutionary phase prior to stellar core formation with gas densities of *sim* 10^{11-12} cm⁻³. This suggests that the evolutionary stage is close to the FHSC formation phase. The two objects are associated with faint X-ray sources, suggesting that they are in very early phase of stellar core formation with magnetic activity. In addition, we found the CO outflow components around both sources which may originate from the young outflows driven by these sources. The masses of these objects are calculated to be *sim* 0.01 – 0.03 *Modot* from the dust continuum emission. Their physical properties are consistent with that expected from the numerical model of forming brown dwarfs. These facts (the X-ray detection, CO outflow association, and FHSC-like spectral energy distributions) strongly indicate that the two objects are proto-BDs or will be in the very early phase of protostars which will evolve more massive protostars if they gain enough mass from the surroundings. The ages of these two objects are likely to be within *sim* 10³ years after the protostellar core (or second core) formation, taking into account the outflow dynamical times (*lessim* 500 yrs).

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Streaming Instability for Particle-Size Distributions

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The streaming instability is thought to play a central role in the early stages of planet formation by enabling the efficient bypass of a number of barriers hindering the formation of planetesimals. We present the first study exploring the efficiency of the linear streaming instability when a particle-size distribution is considered. We find that, for a given dust-to-gas mass ratio, the multi-species streaming instability grows on timescales much longer than those expected when only one dust species is involved. In particular, distributions that contain close-to-order-unity dust-to-gas mass ratios lead to unstable modes that can grow on timescales comparable, or larger, with those of secular instabilities. We anticipate that processes leading to particle segregation and/or concentration can create favourable conditions for the instability to grow fast. Our findings may have important implications for a large number of processes in protoplanetary disks that rely on the streaming instability as usually envisioned for a unique dust species. Our results suggest that the growth rates of other resonant-drag-instabilities may also decrease considerably when multiple species are considered.

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Magnetic activity of the young solar analogue V1358 Ori

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Young, fast rotating single stars can show dramatically different magnetic signatures and levels of magnetic activity as compared with the Sun. While losing angular momentum due to magnetic braking and mass loss through stellar winds, the stars gradually spin down resulting in decreasing levels of activity. Studying magnetic activity on such solar analogues plays a key role in understanding the evolution of solar-like stars and allows a glimpse into the past of the Sun as well. In order to widen our knowledge of the magnetic evolution of the Sun and solar-like stars, magnetic activity of the young solar analogue V1358 Ori is investigated. Fourier analysis of long-term photometric data is used to derive rotational period and activity cycle length, while spectral synthesis is applied on high resolution spectroscopic data in order to derive precise astrophysical parameters. Doppler imaging is performed to recover surface temperature maps for two subsequent intervals. Cross-correlation of the consecutive Doppler maps is used to derive surface differential rotation. The rotational modulation of the chromospheric activity indicators is also investigated. An activity cycle of ≈ 1600 days is detected for V1358 Ori. Doppler imaging revealed a surface temperature distribution dominated by a large polar cap with a few weaker features around the equator. This spot configuration is similar to other maps of young solar analogues from the literature, and supports recent model predictions. We detected solar-like surface differential rotation with a surface shear parameter of $\alpha = 0.016 \pm 0.010$ which fits pretty well to our recently proposed empirical relation between rotation and differential rotation. The chromospheric activity indicators showed a rotational modulation.

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Magnetic field structure in Serpens South

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We made near-infrared polarimetric observations toward Serpens South. This region contains three dense filaments that are roughly parallel to one another. Using the histogram of relative orientations, the three filaments are found to be roughly perpendicular to the global magnetic field. The morphology of the plane-of-sky (POS) magnetic field and molecular gas suggests that the magnetic field plays an important role in the filament formation and evolution. Applying the Davis-Chandrasekhar-Fermi method, the POS magnetic field strengths are estimated to be $30\text{--}140 > \mu\text{G}$. The estimated magnetic field strengths indicate that the filaments are close to magnetically critical. Since protellar and protostellar cores already formed along the filaments, the magnetic diffusion such as a ambipolar diffusion and turbulence reconnection is likely to play an important role in the formation of dense cores. We speculate that the filaments are formed by fragmentation of a sheet-like cloud that was created through the gravitational contraction of a magnetized, turbulent cloud.

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A SiO J = 5 \rightarrow 4 Survey Toward Massive Star Formation Regions

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We performed a survey in the SiO $J = 5 \rightarrow 4$ line toward a sample of 199 Galactic massive star-forming regions at different evolutionary stages with the SMT 10 m and CSO 10.4 m telescopes. The sample consists of 44 infrared dark clouds (IRDCs), 86 protostellar candidates, and 69 young HII regions. We detected SiO $J = 5 \rightarrow 4$ line emission in 102 sources, with a detection rate of 57%, 37%, and 65% for IRDCs, protostellar candidates, and young HII regions, respectively. We find both broad line with Full Widths at Zero Power (FWZP) $> 20 \text{ km s}^{-1}$ and narrow line emissions of SiO in objects at various evolutionary stages, likely associated with high-velocity shocks and low-velocity shocks, respectively. The SiO luminosities do not show apparent differences among various evolutionary stages in our sample. We find no correlation between the SiO abundance and the luminosity-to-mass ratio, indicating that the SiO abundance does not vary significantly in regions at different evolutionary stages of star formation.

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CO Outflow Candidates Toward the W3/4/5 Complex I: The Sample and its Spatial Distribution

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Using the Purple Mountain Observatory Delingha 13.7 m telescope, we conducted a large-scale ^{12}CO ($J = 1-0$) outflow survey (over $\sim 110 \text{ deg}^2$) toward the W3/4/5 complex and its surroundings. In total, 459 outflow candidates were identified. Approximately 62% (284) were located in the Perseus arm, including W3/4/5 complex and its surroundings, while $\sim 35\%$ (162) were located in the Local arm, $\sim 1\%$ (5) in the Outer arm, and $\sim 2\%$ (8) in two interarm regions. This result indicated that star formation was concentrated in the Galactic spiral arms. The detailed spatial distribution of the outflow candidates showed that the Perseus arm presented the most active star formation among the study regions. The W3/4/5 complex is a great region to research massive star formation in a triggered environment. A key region, which has been well-studied by other researches, is in the eastern high-density W3 complex that neighbors the W4 complex. Two shell-like structures in the Local arm contain candidates that can be used to study the impact on star formation imposed by massive or intermediate-mass stars in relatively isolated systems. The majority of outflow candidates in the two interarm regions and the Outer arm are located in filamentary structures.

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The anomalously low (sub)millimeter spectral indices of some protoplanetary disks may be explained by dust self-scattering

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Previous (sub)millimeter observations have found that the spectral indices of dust emission from some young stellar objects are lower than that of the black body emission in the Rayleigh-Jeans limit (i.e., 2.0). In particular, the recent Atacama Large Millimeter Array observations have spatially resolved that the innermost regions of the protoplanetary disks TW Hya and HD 163296 present anomalously low (i.e., < 2.0) millimeter spectral indices. In some previous works,

such anomalously low millimeter spectral indices were considered unphysical and were attributed to measurement errors. The present work clarifies that if the albedo is high and is increasing with frequency, it is possible to reproduce such anomalously low spectral indices when the emission source is optically thick. In addition, to yield lower than 2.0 spectral index at (sub)millimeter bands, the required dust maximum grain size a_{\max} is on the order of 10-100 μm , which is well-consistent with the previously derived a_{\max} values based on multi-wavelength dust polarimetric observations. In light of this, measuring Stokes I spectral index may also serve as an auxiliary approach for assessing whether the observed dust polarization is mainly due to dust scattering or is due to the aligned dust grains.

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Large-scale periodic velocity oscillation in the filamentary cloud G350.54+0.69

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We use APEX mapping observations of ^{13}CO , and C^{18}O (2-1) to investigate the internal gas kinematics of the filamentary cloud G350.54+0.69, composed of the two distinct filaments G350.5-N and G350.5-S. G350.54+0.69 as a whole is supersonic and gravitationally bound. We find a large-scale periodic velocity oscillation along the entire G350.5-N filament with a wavelength of 1.3 pc and an amplitude of 0.12 km/s. Comparing with gravitational-instability induced core formation models, we conjecture that this periodic velocity oscillation could be driven by a combination of longitudinal gravitational instability and a large-scale periodic physical oscillation along the filament. The latter may be an example of an MHD transverse wave. This hypothesis can be tested with Zeeman and dust polarization measurements.

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A Large-field J=1-0 Survey of CO and Its Isotopologues Toward the Cassiopeia A Supernova Remnant

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We have conducted a large-field simultaneous survey of ^{12}CO , ^{13}CO , and C^{18}O $J = 1-0$ emission toward the Cassiopeia A (Cas A) supernova remnant (SNR), which covers a sky area of $3.5^\circ \times 3.1^\circ$. The Cas giant molecular cloud (GMC) mainly consists of three individual clouds with masses on the order of $10^4 - 10^5 M_\odot$. The total mass derived from the ^{13}CO emission of the GMC is $2.1 \times 10^5 M_\odot$ and is $9.5 \times 10^5 M_\odot$ from the ^{12}CO emission. Two regions with broadened ($6-7 \text{ km s}^{-1}$) or asymmetric ^{12}CO line profiles are found in the vicinity (within a $10' \times 10'$ region) of the Cas A SNR, indicating possible interactions between the SNR and the GMC. Using the GAUSSCLUMPS algorithm, 547 ^{13}CO clumps are identified in the GMC, 54% of which are supercritical (i.e. $\alpha_{\text{vir}} < 2$). The mass spectrum of the molecular clumps follows a power-law distribution with an exponent of -2.20 . The pixel-by-pixel column density of the GMC can be fitted with a log-normal probability distribution function (N-PDF). The median column density of molecular hydrogen in the GMC is $1.6 \times 10^{21} \text{ cm}^{-2}$ and half the mass of the GMC is contained in regions with H_2 column density lower than $3 \times 10^{21} \text{ cm}^{-2}$, which is well below the threshold of star formation. The distribution of the YSO candidates in the region shows no agglomeration.

Multiple Rings of Millimeter Dust Emission in the HD 15115 Debris Disk

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We present observations of the HD 15115 debris disk from ALMA at 1.3 mm that capture this intriguing system with the highest resolution ($0''.6$ or 29 AU) at millimeter wavelengths to date. This new ALMA image shows evidence for two rings in the disk separated by a cleared gap. By fitting models directly to the observed visibilities within a MCMC framework, we are able to characterize the millimeter continuum emission and place robust constraints on the disk structure and geometry. In the best-fit model of a power law disk with a Gaussian gap, the disk inner and outer edges are at 43.9 ± 5.8 AU ($0''.89 \pm 0''.12$) and 92.2 ± 2.4 AU ($1''.88 \pm 0''.49$), respectively, with a gap located at 58.9 ± 4.5 AU ($1''.2 \pm 0''.10$) with a fractional depth of 0.88 ± 0.10 and a width of 13.8 ± 5.6 AU ($0''.28 \pm 0''.11$). Since we do not see any evidence at millimeter wavelengths for the dramatic east-west asymmetry seen in scattered light, we conclude that this feature most likely results from a mechanism that only affects small grains. Using dynamical modeling and our constraints on the gap properties, we are able to estimate a mass for the possible planet sculpting the gap to be $0.16 \pm 0.06 M_{\text{Jup}}$.

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Identification of Young Stellar Object candidates in the Gaia DR2 x AllWISE catalogue with machine learning methods

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The second Gaia Data Release (DR2) contains astrometric and photometric data for more than 1.6 billion objects with mean Gaia G magnitude < 20.7 , including many Young Stellar Objects (YSOs) in different evolutionary stages. In order to explore the YSO population of the Milky Way, we combined the Gaia DR2 database with WISE and Planck measurements and made an all-sky probabilistic catalogue of YSOs using machine learning techniques, such as Support Vector Machines, Random Forests, or Neural Networks. Our input catalogue contains 103 million objects from the DR2xAllWISE cross-match table. We classified each object into four main classes: YSOs, extragalactic objects, main-sequence stars and evolved stars. At a 90% probability threshold we identified 1,129,295 YSO candidates. To demonstrate the quality and potential of our YSO catalogue, here we present two applications of it. (1) We explore the 3D structure of the Orion A star forming complex and show that the spatial distribution of the YSOs classified by our procedure is in agreement with recent results from the literature. (2) We use our catalogue to classify published

Gaia Science Alerts. As Gaia measures the sources at multiple epochs, it can efficiently discover transient events, including sudden brightness changes of YSOs caused by dynamic processes of their circumstellar disk. However, in many cases the physical nature of the published alert sources are not known. A cross-check with our new catalogue shows that about 30% more of the published Gaia alerts can most likely be attributed to YSO activity. The catalogue can be also useful to identify YSOs among future Gaia alerts.

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Near-Infrared Variability of Low Mass Stars in IC 1396A and TR 37

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We have monitored nearly a square degree in IC 1396A/Tr 37 over 21 epochs extending over 2014 - 2016 for sources variable in the JHK bands. In our data, 65 ± 8 % of previously identified cluster members show variations, compared with < 0.3 % of field stars. We identify 119 members of Tr 37 on the basis of variability, forming an unbiased sample down to the brown dwarf regime. The K-band luminosity function in Tr 37 is similar to that of IC 348 but shifted to somewhat brighter values, implying that the K- and M-type members of Tr 37 are younger than those in IC 348. We introduce methods to classify the causes of variability, based on behavior in the color-color and color-magnitude diagrams. Accretion hot spots cause larger variations at J than at K with substantial scatter in the diagrams; there are at least a dozen, with the most active resembling EXors. Eleven sources are probably dominated by intervention of dust clumps in their circumstellar disks with color behavior indicating the presence of grains larger than for interstellar dust, presumably due to grain growth in their disks. Thirteen sources have larger variations at K than at J or H. For 11 of them, the temperature fitted to the variable component is very close to $2000K$, suggesting that the changes in output are caused by turbulence at the inner rim of the circumstellar disk exposing previously protected populations of grains.

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On the ALMA observability of nascent massive multiple systems

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Massive young stellar object (MYSOs) form during the collapse of high-mass pre-stellar cores, where infalling molecular material is accreted through a centrifugally-balanced accretion disc that is subject to efficient gravitational instabilities. In the resulting fragmented accretion disc of the MYSO, gaseous clumps and low-mass stellar companions can form, which will influence the future evolution of massive protostars in the Hertzsprung-Russell diagram. We perform dust continuum radiative transfer calculations and compute synthetic images of disc structures modelled by the gravito-radiation-hydrodynamics simulation of a forming MYSO, in order to investigate the *Atacama Large Millime-*

ter/submillimeter Array (ALMA) observability of circumstellar gaseous clumps and forming multiple systems. Both spiral arms and gaseous clumps located at \simeq a few 100 au from the protostar can be resolved by interferometric ALMA Cycle 7 C43-8 and C43-10 observations at band 6 (1.2 mm), using a maximal 0.015'' beam angular resolution and at least 10-30 min exposure time for sources at distances of 1-2 kpc. Our study shows that substructures are observable regardless of their viewing geometry or can be inferred in the case of an edge-viewed disc. The observation probability of the clumps increases with the gradually increasing efficiency of gravitational instability at work as the disc evolves. As a consequence, large discs around MYSOs close to the zero-age-main-sequence line exhibit more substructures than at the end of the gravitational collapse. Our results motivate further observational campaigns devoted to the close surroundings of the massive protostars S255IR-NIRS3 and NGC 6334I-MM1, whose recent outbursts are a probable signature of disc fragmentation and accretion variability.

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Variable Stars in Young Open Cluster NGC 2244

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We present results of a $UBVI_c$ variability survey in the young open cluster NGC 2244. In total, we found 245 variable stars. Most of them, 211 stars, are variables with irregular variations. Furthermore, 23 periodic variables were found. We also detected four candidates for δ Scuti stars and 7 eclipsing binaries. Based on the mid-infrared Spitzer and WISE photometry and near infrared JHK_s 2MASS photometry we classified 104 young stellar sources among our variables: 1 Class I object, 1 Class I/flat spectrum object, 4 flat spectrum objects, 91 Class II objects and 7 transition disk objects. This classification, together with $r'i'H\alpha$ IPHAS photometry and JHK UKIDSS photometry, were used for identification of pre-main sequence stars among irregular and periodic variables. In this way, 97 CTTS candidates (96 irregular and one periodic variable), 68 WTTS candidates (54 irregular and 14 periodic variables) and 6 Herbig Ae/Be stars were found. For 223 variable stars we calculated membership probability based on proper motions from Gaia DR2 catalogue. Majority of them, 143 stars, are cluster members with probability greater than 70 percent. For only 36 variable stars the membership probability is smaller than 20 percent.

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On the planetary interpretation of multiple gaps and rings in protoplanetary disks seen by ALMA

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It has been recently suggested that the multiple concentric rings and gaps discovered by ALMA in many protoplanetary disks may be produced by a single planet, as a result of the complex propagation and dissipation of the multiple spiral density waves it excites in the disk. Numerical efforts to verify this idea have largely utilized the so-called locally isothermal approximation with a prescribed disk temperature profile. However, in protoplanetary disks this approximation does not provide an accurate description of the density wave dynamics on scales of tens of au. Moreover, we show that locally isothermal simulations tend to overestimate the contrast of ring and gap features, as well as misrepresent their positions, when compared to simulations in which the energy equation is evolved explicitly. This outcome is caused by the non-conservation of the angular momentum flux of linear perturbations in locally isothermal disks. We demonstrate this effect using simulations of locally isothermal and adiabatic disks (with essentially identical temperature profiles) and show how the dust distributions, probed by mm wavelength observations, differ between the two cases. Locally isothermal simulations may thus underestimate the masses of planets responsible for the formation

of multiple gaps and rings on scales of tens of au observed by ALMA. We suggest that caution should be exercised in using the locally isothermal simulations to explore planet-disk interaction, as well as in other studies of wave-like phenomena in astrophysical disks.

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An Origin for the Angular Momentum of Molecular Cloud Cores: a Prediction from Filament Fragmentation

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The angular momentum of a molecular cloud core plays a key role in star formation, since it is directly related to the outflow and the jet emanating from the new-born star and it eventually results in the formation of the protoplanetary disk. However, the origin of the core rotation and its time evolution are not well understood. Recent observations reveal that molecular clouds exhibit a ubiquity of filamentary structures and that star forming cores are associated with the densest filaments. Since these results suggest that dense cores form primarily in filaments, the mechanism of core formation from filament fragmentation should explain the distribution of the angular momentum of these cores. In this paper we analyze the relation between velocity fluctuations along the filament close to equilibrium and the angular momentum of the cores formed along its crest. We first find that an isotropic velocity fluctuation that follows the three-dimensional Kolmogorov spectrum does not reproduce the observed angular momentum of molecular cloud cores. We then identify the need for a large power at small scales and study the effect of three power spectrum models. We show that the one-dimensional Kolmogorov power spectrum with a slope $-5/3$ and an anisotropic model with reasonable parameters are compatible with the observations. Our results stress the importance of more detailed and systematic observations of both the velocity structure along filaments and the angular momentum distribution of molecular cloud cores to determine the validity of the mechanism of core formation from filamentary molecular clouds.

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Molecular analysis of a high-mass prestellar core candidate in W43-MM1

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High-mass analogues of low-mass prestellar cores are searched for to constrain the models of high-mass star formation. Several high-mass cores, at various evolutionary stages, have been recently identified towards the massive star-forming region W43-MM1 and amongst them a high-mass prestellar core candidate. We aim to characterise the chemistry in this high-mass prestellar core candidate, referred to as W43-MM1 core #6, and its environment. Using ALMA high-spatial resolution data of W43-MM1, we have studied the molecular content of core #6 and a neighbouring high-mass protostellar core, referred to as #3, which is similar in size and mass to core #6. We first subtracted the continuum emission using a method based on the density distribution of the intensities on each pixel. Then, from the distribution of detected molecules, we identified the molecules centred on the prestellar core candidate (core #6) and those associated to shocks related to outflows and filament formation. Then we constrained the column densities

and temperatures of the molecules detected towards the two cores. While core #3 appears to contain a hot core with a temperature of about 190 K, core #6 seems to have a lower temperature in the range from 20 K to 90 K from a rotational diagram analysis. We have considered different source sizes for core #6 and the comparison of the abundances of the detected molecules towards the core with various interstellar sources shows that it is compatible with a core of size 1000 au with $T = 20\text{--}90$ K or a core of size 500 au with $T \sim 80$ K. Core #6 of W43-MM1 remains one of the best high-mass prestellar core candidates even if we cannot exclude that it is at the very beginning of the protostellar phase of high-mass star formation.

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Opening the Treasure Chest in Carina

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Pillars and globules are the best examples of the impact of the radiation and wind from massive stars on the surrounding interstellar medium. We mapped the G287.84-0.82 cometary globule (with the Treasure Chest cluster embedded in it) in the South Pillars region of Carina (i) in [C II], $63\mu\text{m}$ [O I], and CO(11–10) using the heterodyne receiver array upGREAT on SOFIA and (ii) in $J=2\text{--}1$ transitions of CO, ^{13}CO , C^{18}O , and $J=3\text{--}2$ transitions of H_2CO using the APEX telescope in Chile. We used these data to probe the morphology, kinematics, and physical conditions of the molecular gas and the photon-dominated regions (PDRs) in G287.84-0.82. The velocity-resolved observations of [C II] and [O I] suggest that the overall structure of the pillar (with red-shifted photoevaporating tails) is consistent with the effect of FUV radiation and winds from η Car and O stars in Trumpler 16. The gas in the head of the pillar is strongly influenced by the embedded cluster, whose brightest member is an O9.5 V star, CPD -59°2661. The emission of the [C II] and [O I] lines peak at a position close to the embedded star, while all the other tracers peak at another position lying to the northeast consistent with gas being compressed by the expanding PDR created by the embedded cluster. The molecular gas inside the globule was probed with the $J=2\text{--}1$ transitions of CO and isotopologs as well as H_2CO , and analyzed using a non-local thermodynamic equilibrium model (escape-probability approach), while we used PDR models to derive the physical conditions of the PDR. We identify at least two PDR gas components; the diffuse part ($\sim 10^4\text{ cm}^{-3}$) is traced by [C II], while the dense ($n \sim 2\text{--}8 \times 10^5\text{ cm}^{-3}$) part is traced by [C II], [O I], and CO(11–10). Using the $F=2\text{--}1$ transition of [13CII] detected at 50 positions in the region, we derived optical depths (0.9–5), excitation temperatures of [C II] (80–255 K), and $N(\text{C}^+)$ of $0.3\text{--}1 \times 10^{19}\text{ cm}^{-2}$. The total mass of the globule is $\sim 1,000\text{ M}_\odot$, about half of which is traced by [C II]. The dense PDR gas has a thermal pressure of $10^7\text{--}10^8\text{ K cm}^{-3}$, which is similar to the values observed in other regions.

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Two epoch spectro-imagery of FS Tau B outflow system

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Herbig-Haro (HH) flows exhibit a large variety of morphological and kinematical structures such as bow shocks, Mach disks, and deflection shocks. Both proper motion (PM) and radial velocity investigations are essential to understand the physical nature of such structures.

We investigate the kinematics and PM of spectrally separated structures in the FS Tau B HH flow. Collating these data makes it possible to understand the origin of these structures and to explain the unusual behavior of the jet. On

the other hand, the study of emission profiles in the associated reflection nebulae allows us to consider the source of the outflow both from edge-on and pole-on points of view.

We present the observational results obtained with the 6 m telescope at the Special Astrophysical Observatory of the Russian Academy of Sciences using the SCORPIO multimode focal reducer with a scanning Fabry-Perot interferometer. Two epochs of the observations of the FS Tau B region in H α emission (2001 and 2012) allowed us to measure the PM of the spectrally separated inner structures of the jet.

In addition to already known emission structures in the FS Tau B system, we discover new features in the extended part of the jet and in the counter-jet. Moreover, we reveal a new HH knot in the HH 276 independent outflow system and point out its presumable source. In the terminal working surface of the jet, structures with different radial velocities have PMs of the same value. This result can be interpreted as the direct observation of bow-shock and Mach disk regions. A bar-like structure, located southwest from the source demonstrates zero PM and can be considered as one more example of deflection shock. An analysis of H α profiles in the reflection nebulae R1 and R3 indicates the uniqueness of this object, which can be studied in pole-on and edge-on directions simultaneously.

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Nobeyama 45-m Mapping Observations toward Nearby Molecular Clouds, Orion A, Aquila Rift, and M17: Project overview

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We carried out mapping observations toward three nearby molecular clouds, Orion A, Aquila Rift, and M17, using a new 100 GHz receiver, FOREST, on the Nobeyama 45-m telescope. In the present paper, we describe the details of the data obtained such as intensity calibration, data sensitivity, angular resolution, and velocity resolution. Each target contains at least one high-mass star-forming region. The target molecular lines were ¹²CO ($J = 1 - 0$), ¹³CO ($J = 1 - 0$), C¹⁸O ($J = 1 - 0$), N₂H⁺ ($J = 1 - 0$), and CCS ($J_N = 8_7 - 7_6$), with which we covered the density range of 10² cm⁻³ to 10⁶ cm⁻³ with an angular resolution of *sim* 20 arcsec and a velocity resolution of *sim* 0.1 km s⁻¹. Assuming the representative distances of 414 pc, 436 pc, and 2.1 kpc, the maps of Orion A, Aquila Rift, and M17 cover most of the densest parts with areas of about 7 pc *times* 15 pc, 7 pc *times* 7 pc, and 36 pc *times* 18 pc, respectively. On the basis of the ¹³CO column density distribution, the total molecular masses are derived to be 3.86 *times* 10⁴ Modot, 2.67 *times* 10⁴ Modot, and 8.1 *times* 10⁵ Modot for Orion A, Aquila Rift, and M17, respectively. For all the clouds, the H₂ column density exceeds the theoretical threshold for high-mass star formation of *gt* *sim* 1 g cm⁻², only toward the regions which contain current high-mass star-forming sites. For other areas, further mass accretion or dynamical compression would be necessary for future high-mass star formation. This is consistent with the current star formation activity. Using the ¹²CO data, we demonstrate that our data have enough capability to identify molecular outflows, and for Aquila Rift, we identify 4 new outflow candidates. The scientific results will be discussed in details in separate papers.

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Nobeyama 45-m Mapping Observations toward Orion A. III. Multi-Line Observations toward an Outflow-shocked Region, OMC-2 FIR 4

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We present the results of mapping observations toward an outflow-shocked region, OMC-2 FIR 4 using the Nobeyama 45-m telescope. We observed the area in ^{13}CO ($J = 1 - 0$), C^{18}O ($J = 1 - 0$), N_2H^+ ($J = 1 - 0$), CCS ($J_N = 8_7 - 7_6$), HCO^+ ($J = 1 - 0$), H^{13}CO^+ ($J = 1 - 0$), HN^{13}C ($J = 1 - 0$), H^{13}CN ($J = 1 - 0$), DNC ($J = 1 - 0$), N_2D^+ ($J = 1 - 0$), and DC_3N ($J = 9 - 8$). We detected a dense molecular clump that contains FIR 4/5. We also detected in ^{13}CO blueshifted and redshifted components driven presumably by protostellar outflows in this region. The axes of the FIR 3 and VLA 13 outflows, projected on the plane of the sky, appear to point toward the FIR 4 clump, suggesting that the clump may be compressed by protostellar outflows from Class I sources, FIR 3 and VLA 13. Applying the hyperfine fit of N_2H^+ lines, we estimated the excitation temperature to be *sim* 20 K. The high excitation temperature is consistent with the fact that the clump contains protostars. The CCS emission was detected in this region for the first time. Its abundance is estimated to be a few *times* 10^{-12} , indicating that the region is chemically evolved at *sim* 10^5 years, which is comparable to the typical lifetime of the Class I protostars. This timescale is consistent with the scenario that star formation in FIR 4 is triggered by dynamical compression of the protostellar outflows. The $[\text{HNC}]/[\text{HCN}]$ ratio is evaluated to be *sim* 0.5 in the dense clump and the outflow lobes, whereas it is somewhat larger in the envelope of the dense clump. The small $[\text{HNC}]/[\text{HCN}]$ ratio indicates that the HNC formation was prevented due to high temperatures. Such high temperatures seem to be consistent with the scenario that either protostellar radiation or outflow compression, or both, affected the thermal properties of this region.

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Gaia-DR2 distance to the W3 Complex in the Perseus Arm

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The Perseus Arm is the closest Galactic spiral arm from the Sun, offering an excellent opportunity to study in detail its stellar population. However, its distance has been controversial with discrepancies by a factor of two. Kinematic distances are in the range 3.9–4.2 kpc as compared to 1.9–2.3 kpc from spectrophotometric and trigonometric parallaxes, reinforcing previous claims that this arm exhibits peculiar velocities. We used the astrometric information of a sample of 31 OB stars from the star-forming W3 Complex to identify another 37 W3 members and to derive its distance from their Gaia-DR2 parallaxes with improved accuracy. The Gaia-DR2 distance to the W3 Complex, $2.14^{+0.08}_{-0.07}$ kpc, coincides with the previous stellar distances of ~ 2 kpc. The Gaia-DR2 parallaxes tentatively show differential distances for different parts of the W3 Complex: W3 Main, located to the NE direction, is at $2.30^{+0.19}_{-0.16}$ kpc.

kpc, the W3 Cluster (IC 1795), in the central region of the complex, is at $2.17^{+0.12}_{-0.11}$ kpc, and W3(OH) is at $2.00^{+0.29}_{-0.23}$ kpc to the SW direction. The W3 Cluster is the oldest region, indicating that it triggered the formation of the other two star-forming regions located at the edges of an expanding shell around the cluster.

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ALMA observations require slower Core Accretion runaway growth

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Thanks to recent high resolution ALMA observations, there is an accumulating evidence for presence of giant planets with masses from ~ 0.01 Jupiter mass to a few Jupiter mass with separations up to 100 AU in the annular structures observed in young protoplanetary discs. We point out that these observations set unique “live” constraints on the process of gas accretion onto sub-Jovian planets that were not previously available. Accordingly, we use a population synthesis approach in a new way: we build time-resolved models and compare the properties of the synthetic planets with the ALMA data at the same age. Applying the widely used gas accretion formulae leads to a deficit of sub-Jovian planets and an over-abundance of a few Jupiter mass planets compared to observations. We find that gas accretion rate onto planets needs to be suppressed by about an order of magnitude to match the observed planet mass function. This slower gas giant growth predicts that the planet mass should correlate positively with the age of the protoplanetary disc, albeit with a large scatter. This effect is not clearly present in the ALMA data but may be confirmed in the near future with more observations.

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SOFIA/EXES observations of warm H₂ at high spectral resolution: witnessing para-to-ortho conversion behind a molecular shock wave in HH7

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Spectrally-resolved observations of three pure rotational lines of H₂, conducted with the EXES instrument on SOFIA toward the classic bow shock HH7, reveal systematic velocity shifts between the S(5) line of ortho-H₂ and the two para-H₂ lines [S(4) and S(6)] lying immediately above and below it on the rotational ladder. These shifts, reported here for the first time, imply that we are witnessing the conversion of para-H₂ to ortho-H₂ within a shock wave driven by an outflow from a young stellar object. The observations are in good agreement with the predictions of models for non-dissociative, C-type molecular shocks. They provide a clear demonstration of the chemical changes wrought by interstellar shock waves, in this case the conversion of para-H₂ to ortho-H₂ in reactive collisions with atomic hydrogen, and provide among the most compelling evidence yet obtained for C-type shocks in which the flow velocity changes continuously.

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Evidence for disc regulation in the lowest-mass stars of the young stellar cluster NGC 2264

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In the pre-main-sequence stage, star-disc interactions have been shown to remove stellar angular momentum and regulate the rotation periods of stars with M2 and earlier spectral types. Whether disc regulation also extends to stars with later spectral types still remains a matter of debate. Here we present a star-disc interaction study in a sample of over 180 stars with spectral types M3 and later (corresponding to stellar masses $\leq 0.3 M_{\odot}$) in young stellar cluster NGC 2264. Combining rotation periods from the literature, new and literature spectral types, and newly presented deep Spitzer observations, we show that stars with masses below $0.3 M_{\odot}$ with discs also rotate slower than stars without a disc in the same mass regime. Our results demonstrate that disc-regulation still operates in these low-mass stars, although the efficiency of this process might be lower than in higher-mass objects. We confirm that stars with spectral types earlier and later than M2 have distinct period distributions and that stars with spectral types M5 and later rotate even faster M3 and M4-type stars.

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A Simple Non-equilibrium Feedback Model for Galaxy-Scale Star Formation: Delayed Feedback and SFR Scatter

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We explore a class of simple non-equilibrium star formation models within the framework of a feedback-regulated model of the ISM, applicable to kiloparsec-scale resolved star formation relations (e.g. Kennicutt-Schmidt). Combining a Toomre-Q-dependent local star formation efficiency per free-fall time with a model for delayed feedback, we are able to match the normalization and scatter of resolved star formation scaling relations. In particular, this simple model suggests that large (\sim dex) variations in star formation rates (SFRs) on kiloparsec scales may be due to the fact that supernova feedback is not instantaneous following star formation. The scatter in SFRs at constant gas surface density in a galaxy then depends on the properties of feedback and when we observe its star-forming regions at various points throughout their collapse/star formation “cycles”. This has the following important observational consequences: (1) the scatter and normalization of the Kennicutt-Schmidt relation are relatively insensitive to the local (small-scale) star formation efficiency, (2) but gas depletion times and velocity dispersions are; (3) the scatter in and normalization of the Kennicutt-Schmidt relation is a sensitive probe of the feedback timescale and strength; (4) even in a model where \tilde{Q}_{gas} deterministically dictates star formation locally, time evolution, variation in local conditions (e.g., gas fractions and dynamical times), and variations between galaxies can destroy much of the observable correlation between SFR and \tilde{Q}_{gas} in resolved galaxy surveys. Additionally, this model exhibits large scatter in SFRs at low gas surface densities, in agreement with observations of flat outer HI disk velocity dispersion profiles.

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Do star clusters form in a completely mass-segregated way?

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ALMA observations of the Serpens South star-forming region suggest that stellar protoclusters may be completely mass segregated at birth. Independent observations also suggest that embedded clusters form segregated by mass. As the primordial mass segregation seems to be lost over time, we aim to study on which timescale an initially perfectly mass-segregated star cluster becomes indistinguishable from an initially not mass-segregated cluster. As an example, the Orion Nebula Cluster (ONC) is also discussed. We used N -body simulations of star clusters with various masses and two different degrees of primordial mass segregation. We analysed their energy redistribution through two-body relaxation to quantify the time when the models agree in terms of mass segregation, which sets in only dynamically in the models that are primordially not mass segregated. A comprehensive cross-matched catalogue combining optical, infrared, and X-ray surveys of ONC members was also compiled and made available. The models evolve to a similar radial distribution of high-mass stars after the core collapse (about half a median two-body relaxation time, t_{rh}) and become observationally indistinguishable from the point of view of mass segregation at time $\tau_v \approx 3.3 t_{\text{rh}}$. In the case of the ONC, using the distribution of high-mass stars, we may not rule out either evolutionary scenario (regardless of whether they are initially mass segregated). When we account for extinction and elongation of the ONC, as reported elsewhere, an initially perfectly mass-segregated state seems to be more consistent with the observed cluster.

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An Inner Disk in the Large Gap of the Transition Disk SR 24S

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We report new Atacama Large Millimeter/sub-millimeter Array (ALMA) Band 3 observations at 2.75 mm of the TD around SR 24S with an angular resolution of $\sim 0.11 \times 0.09$ arcsec and a peak signal-to-noise ratio of ~ 24 . We detect an inner disk and a mostly symmetric ring-like structure that peaks at ~ 0.32 arcsec, that is ~ 37 au at a distance of ~ 114.4 pc. The full width at half maximum of this ring is ~ 28 au. We analyze the observed structures by fitting the dust continuum visibilities using different models for the intensity profile, and compare with previous ALMA observations of the same disk at 0.45 mm and 1.30 mm. We qualitatively compare the results of these fits with theoretical predictions of different scenarios for the formation of a cavity or large gap. The comparison of the dust continuum structure between different ALMA bands indicates that photoevaporation and dead zone can be excluded as leading mechanisms for the cavity formation in SR 24S disk, leaving the planet scenario (single or multiple planets) as the most plausible mechanism. We compared the 2.75 mm emission with published (sub-)centimeter data and find that the inner disk is likely tracing dust thermal emission. This implies that any companion in the system should allow dust to move inwards throughout the gap and replenish the inner disk. In the case of one single planet, this puts strong constraints on the mass of the potential planet inside the cavity and the disk viscosity of about $\lesssim 5 M_{\text{Jup}}$ and $\alpha \sim 10^{-4} - 10^{-3}$, respectively.

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Modeling the Protoplanetary Disks of Two Brown Dwarfs in the Taurus Molecular Cloud

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Measuring the properties of protoplanetary disks around brown dwarfs is central to understanding the formation of brown dwarfs and their planetary companions. We present modeling of CFHT Tau 4 and 2M0444, two brown dwarfs with protoplanetary disks in the Taurus Molecular Cloud. By combining modeling of the spectral energy distributions and ALMA images, we obtain disk radii and masses for these objects; these parameters can be used to constrain brown dwarf formation and planet formation, respectively. We find that the disk around CFHT Tau 4 has a total mass of $0.42 M_{Jup}$ and a radius of 80 au; we find 2M0444's disk to have a mass of $2.05 M_{Jup}$ and a radius of 100 au. These radii are more consistent with those predicted by theoretical simulations of brown dwarf formation via undisturbed condensation from a mass reservoir than those predicted by ejection from the formation region. Furthermore, the disk mass of 2M0444 suggests that planet formation may be possible in this disk, although the disk of CFHT Tau 4 is likely not massive enough to form planets. The disk properties measured here provide constraints to theoretical models of brown dwarf formation and the formation of their planetary companions.

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The time evolution of dusty protoplanetary disc radii: observed and physical radii differ

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Proto-planetary disc surveys conducted with ALMA are measuring disc radii in multiple star forming regions. The disc radius is a fundamental quantity to diagnose whether discs undergo viscous spreading, discriminating between viscosity or angular momentum removal by winds as drivers of disc evolution. Observationally, however, the sub-mm continuum emission is dominated by the dust, which also drifts inwards, complicating the picture. In this paper we investigate, using theoretical models of dust grain growth and radial drift, how the radii of dusty viscous protoplanetary discs evolve with time. Despite the existence of a sharp outer edge in the dust distribution, we find that the radius enclosing most of the dust mass increases with time, closely following the evolution of the gas radius. This behaviour arises because, although dust initially grows and drifts rapidly onto the star, the residual dust retained on Myr timescales is relatively well coupled to the gas. Observing the expansion of the dust disc requires using definitions based on high fractions of the disc flux (e.g. 95 per cent) and very long integrations with ALMA, because the dust grains in the outer part of the disc are small and have a low sub-mm opacity. We show that existing surveys lack the sensitivity to detect viscous spreading. The disc radii they measure do not trace the mass radius or the sharp outer edge in the dust distribution, but the outer limit of where the grains have significant sub-mm opacity. We predict that these observed radii should shrink with time.

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On the millimetre continuum flux-radius correlation of proto-planetary discs

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A correlation between proto-planetary disc radii and sub-mm fluxes has been recently reported. In this Letter we show that the correlation is a sensitive probe of grain growth processes. Using models of grain growth and drift, we have shown in a companion paper that the observed disc radii trace where the dust grains are large enough to have a significant sub-mm opacity. We show that the observed correlation emerges naturally if the maximum grain size is set by radial drift, implying relatively low values of the viscous α parameter $\lesssim 0.001$. In this case the relation has an almost universal normalisation, while if the grain size is set by fragmentation the flux at a given radius depends on the dust-to-gas ratio. We highlight two observational consequences of the fact that radial drift limits the grain size. The first is that the dust masses measured from the sub-mm could be overestimated by a factor of a few. The second is that the correlation should be present also at longer wavelengths (e.g. 3 mm), with a normalisation factor that scales as the square of the observing frequency as in the optically thick case.

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Carbon radio recombination lines from gigahertz to megahertz frequencies towards Orion A

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Context. The combined use of carbon radio recombination lines (CRRLs) and the 158 μm -[CII] line is a powerful tool for the study of the energetics and physical conditions (e.g., temperature and density) of photodissociation regions (PDRs). However, there are few observational studies that exploit this synergy.

Aims. Here we explore the relation between CRRLs and the 158 μm -[CII] line in light of new observations and models.

Methods. We present new and existing observations of CRRLs in the frequency range 0.15–230 GHz with ALMA, VLA, the GBT, Effelsberg 100m, and LOFAR towards Orion A (M42). We complement these observations with SOFIA observations of the 158 μm -[CII] line. We studied two PDRs: the foreground atomic gas, known as the Veil, and the dense PDR between the HII region and the background molecular cloud.

Results. In the Veil we are able to determine the gas temperature and electron density, which we use to measure the ionization parameter and the photoelectric heating efficiency. In the dense PDR, we are able to identify a layered PDR structure at the surface of the molecular cloud to the south of the Trapezium cluster. There we find that the radio lines trace the colder portion of the ionized carbon layer, the $\text{C}^+/\text{C}/\text{CO}$ interface. By modeling the emission of the 158 μm -[CII] line and CRRLs as arising from a PDR we derive a thermal pressure $> 5 \times 10^7 \text{ K cm}^{-3}$ and a radiation field $G_0 \approx 10^5$ close to the Trapezium.

Conclusions. This work provides additional observational support for the use of CRRLs and the 158 μm -[CII] line as complementary tools to study dense and diffuse PDRs, and highlights the usefulness of CRRLs as probes of the $\text{C}^+/\text{C}/\text{CO}$ interface.

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Dynamical evolution of star-forming regions: III. Unbound stars and predictions for Gaia

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We use N -body simulations to probe the early phases of the dynamical evolution of star-forming regions and focus on mass and velocity distributions of unbound stars. In this parameter space study, we vary the initial virial ratio and degree of spatial and kinematic substructure and analyse the fraction of stars that become unbound in two different mass classes (above and below $8 M_{\odot}$). We find that the fraction of unbound stars differs depending on the initial conditions. After 10 Myr, in initially highly subvirial, substructured simulations, the high-mass and lower-mass unbound fractions are similar at ~ 23 per cent. In initially virialised, substructured simulations, we find only ~ 16 per cent of all high-mass stars are unbound, whereas ~ 37 per cent of all lower-mass stars are. The velocity distributions of unbound stars only show differences for extremely different initial conditions. The distributions are dominated by large numbers of lower-mass stars becoming unbound just above the escape velocity of $\sim 3 \text{ km s}^{-1}$ with unbound high-mass stars moving faster on average than lower-mass unbound stars. We see no high-mass runaway stars (velocity $> 30 \text{ km s}^{-1}$) from any of our initial conditions and only an occasional lower-mass runaway star from initially subvirial/substructured simulations. In our simulations, we find a small number of lower-mass walkaway stars (with velocity $5\text{--}30 \text{ km s}^{-1}$) from all of our initial conditions. These walkaway stars should be observable around many nearby star-forming regions with Gaia.

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A survey of molecular cores in M17 SWex

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A survey of molecular cores covering the infrared dark cloud known as the M17 southwest extension (M17 SWex) has been carried out with the 45 m Nobeyama Radio Telescope. Based on the N_2H^+ ($J=1-0$) data obtained, we have identified 46 individual cores whose masses are in the range 43 to $3026 M_{\odot}$. We examined the relationship between the physical parameters of the cores and those of young stellar objects (YSOs) associated with the cores found in the literature. The comparison of the virial mass and the core mass indicates that most of the cores can be gravitationally stable if we assume a large external pressure. Among the 46 cores, we found four massive cores with YSOs. They have large mass of $>1000 M_{\odot}$ and line width of $> 2.5 \text{ km s}^{-1}$ which are similar to those of clumps forming high mass stars. However, previous studies have shown that there is no active massive star formation in this region. Recent measurements of near-infrared polarization infer that the magnetic field around M17 SWex is likely to be strong enough to support the cores against self-gravity. We therefore suggest that the magnetic field may prevent the cores from collapsing, causing the low-level of massive star formation in M17 SWex.

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Why does ammonia not freeze out in the center of pre-stellar cores?

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We carried out a parameter-space exploration of the ammonia abundance in the pre-stellar core L1544, where it has been observed to increase toward the center of the core with no signs of freeze-out onto grain surfaces. We considered static and dynamical physical models coupled with elaborate chemical and radiative transfer calculations, and explored

the effects of varying model parameters on the (ortho+para) ammonia abundance profile. None of our models are able to reproduce the inward-increasing tendency in the observed profile; ammonia depletion always occurs in the center of the core. In particular, our study shows that including the chemical desorption process, where exothermic association reactions on the grain surface can result in the immediate desorption of the product molecule, leads to ammonia abundances that are over an order of magnitude above the observed level in the innermost 15000 au of the core – at least when one employs a constant efficiency for the chemical desorption process irrespective of the ice composition. Our results seemingly constrain the chemical desorption efficiency of ammonia on water ice to below 1%. It is increasingly evident that time-dependent effects must be considered so that the results of chemical models can be reconciled with observations.

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Sticking Properties of Silicates in Planetesimal Formation Revisited

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In the past, laboratory experiments and theoretical calculations showed a mismatch in derived sticking properties of silicates in the context of planetesimal formation. It has been proposed by Kimura et al. (2015) that this mismatch is due to the value of the surface energy assumed, supposedly correlated to the presence or lack of water layers of different thickness on a grain's surface. We present tensile strength measurements of dust aggregates with different water content here. The results are in support of the suggestion by Kimura et al. (2015). Dry samples show increased strengths by a factor of up to 10 over wet samples. A high value of $\gamma = 0.2 \text{ J m}^{-2}$ likely applies to the dry low pressure conditions of protoplanetary disks and should be used in the future.

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A Radial Velocity Survey of Embedded Sources in the Rho Ophiuchi Cluster

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We present the results of a radial velocity survey of young stellar objects in early stages of evolution in the core of the L 1688 molecular cloud. New and archival spectra obtained with four high resolution infrared spectrographs were analysed using Markov Chain Monte Carlo techniques that simultaneously fit for the radial velocity, T_{eff} , $v \sin i$, and veiling by comparison with synthetic spectra. The radial velocity distribution for 32 objects, most with Class I or Flat-spectrum spectral energy distributions, is marginally gaussian, with a higher dispersion relative to optical surveys at the 2σ level. When comparing the results from both proper motion and radial velocity surveys in L 1688, there is a trend for the 1-D dispersions to be higher for samples of Class I/Flat-spectrum young stellar objects that reside in the cloud core compared to Class II/III dominated samples which are located in the lower extinction periphery. In addition, there is a velocity gradient along the major axis of the cloud core that appears more pronounced than that derived from optically visible objects at the cloud edges. If these higher dispersions for Class I/Flat-spectrum objects are confirmed by future surveys, this could imply a supervirial state for the less evolved objects in the cloud core and be a signature of the initial collapse and rebound of the cluster as suggested by recent simulations of cluster evolution.

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Discovery of an au-scale excess in millimeter emission of TW Hya

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We report the detection of an excess in dust continuum emission at 233 GHz (1.3 mm in wavelength) in the protoplanetary disk around TW Hya revealed through high-sensitivity observations at ~ 3 au resolution with the Atacama Large Millimeter/submillimeter Array (ALMA). The sensitivity of the 233 GHz image has been improved by a factor of 3 with regard to that of our previous cycle 3 observations. The overall structure is mostly axisymmetric, and there are apparent gaps at 25 and 41 au as previously reported. The most remarkable new finding is a few au-scale excess emission in the south-west part of the protoplanetary disk. The excess emission is located at 52 au from the disk center and is 1.5 times brighter than the surrounding protoplanetary disk at a significance of 12σ . We performed a visibility fitting to the extracted emission after subtracting the axisymmetric protoplanetary disk emission and found that the inferred size and the total flux density of the excess emission are 4.4×1.0 au and $250 \mu\text{Jy}$, respectively. The dust mass of the excess emission corresponds to $0.03 M_{\oplus}$ if a dust temperature of 18 K is assumed. Since the excess emission can also be marginally identified in the Band 7 image at almost the same position, the feature is unlikely to be a background source. The excess emission can be explained by a dust clump accumulated in a small elongated vortex or a massive circumplanetary disk around a Neptune mass forming-planet.

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Disk masses in the Orion Molecular Cloud-2: distinguishing time and environment

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The mass evolution of protoplanetary disks is driven by both internal processes and external factors, such as photoevaporation. Disentangling these two effects, however, has remained difficult. We measure the dust masses of a sample of 132 disks in the Orion Molecular Cloud (OMC)-2 region, and compare them to (i) externally photoevaporated disks in the Trapezium cluster, and (ii) disks in nearby low-mass star forming regions (SFRs). This allows us to test if initial disk properties are the same in high- and low-mass SFRs, and enables a direct measurement of the effect of external photoevaporation on disks. A $\sim 20' \times 4'$ mosaic of 3 mm continuum observations from the Atacama Large Millimeter/submillimeter Array (ALMA) was used to measure the fluxes of 132 disks and 35 protostars > 0.5 pc away from the Trapezium. We identify and characterize a sample of 34 point sources not included in the Spitzer catalog on which the sample is based. Of the disks, 37 (28%) are detected, with masses ranging from $7\text{--}270 M_{\oplus}$. The detection rate for protostars is higher at 69%. Disks near the Trapezium are found to be less massive by a factor $0.18^{+0.18}_{-0.11}$, implying a mass loss rate of $8 \times 10^{-8} M_{\odot} \text{ yr}^{-1}$. Our observations allow us to distinguish the impact of time and environment on disk evolution in a single SFR. The disk mass distribution in OMC-2 is statistically indistinguishable from that in nearby low-mass SFRs, like Lupus and Taurus. We conclude that age is the main factor determining the evolution of these disks. This result is robust with respect to assumptions of dust temperature, sample incompleteness and biases. The difference between the OMC-2 and Trapezium cluster samples is consistent with mass loss driven by far-ultraviolet radiation near the Trapezium. Together, this implies that in isolation, disk formation and evolution proceed similarly, regardless of cloud mass.

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New constraints on the initial parameters of low-mass star formation from chemical modeling

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The complexity of physico-chemical models of star formation is increasing, with models that take into account new processes and more realistic setups. These models allow astrochemists to compute the evolution of chemical species throughout star formation. Hence, comparing the outputs of such models to observations allows to bring new constraints on star formation. The work presented in this paper is based on the recent public release of a database of radiation hydrodynamical low-mass star formation models. We used this database as physical parameters to compute the time dependent chemical composition of collapsing cores with a 3-phase gas-grain model. The results are analyzed to find chemical tracers of the initial physical parameters of collapse such as the mass, radius, temperature, density, and free-fall time. They are also compared to observed molecular abundances of Class 0 protostars. We find numerous tracers of the initial parameters of collapse, except for the initial mass. More particularly, we find that gas phase CH₃CN, NS and OCS trace the initial temperature, while H₂CS trace the initial density and free-fall time of the parent cloud. The comparison of our results with a sample of 12 Class 0 low mass protostars allows us to constrain the initial parameters of collapse of low-mass prestellar cores. We find that low-mass protostars are preferentially formed within large cores with radii greater than 20000 au, masses between 2 and 4 M_{\odot} , temperatures lower or equal to 15 K, and densities between 6×10^4 and 2.5×10^5 cm⁻³, corresponding to free-fall times between 100 and 200 kyrs.

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Global evolution of a gravitoviscous protoplanetary disk. I. The importance of the inner sub-au region

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The central region of a circumstellar disk is difficult to resolve in global numerical simulations of collapsing cloud cores, but its effect on the evolution of the entire disk can be significant. We use numerical hydrodynamics simulations to model the long-term evolution of self-gravitating and viscous circumstellar disks in the thin-disk limit. Simulations start from the gravitational collapse of prestellar cores of 0.5–1.0 M_{\odot} and both gaseous and dusty subsystems were considered, including a model for dust growth. The inner unresolved 1.0 au of the disk is replaced with a central “smart” cell (CSC) – a simplified model that simulates physical processes that may occur in this region. We found that the mass transport rate through the CSC has an appreciable effect on the evolution of the entire disk. Models with slow mass transport form more massive and warmer disks and they are more susceptible to gravitational instability and fragmentation, including a newly identified episodic mode of disk fragmentation in the T Tauri phase of disk evolution. Models with slow mass transport through the CSC feature episodic accretion and luminosity bursts in the early evolution, while models with fast transport are characterized by a steadily declining accretion rate with low-amplitude flickering. Dust grows to a larger, decimeter size in the slow transport models and efficiently drifts in the CSC, where it accumulates reaching the limit when streaming instability becomes operational. We argue that gravitational instability, together with streaming instability likely operating in the inner disk regions, constitute two concurrent planet-forming mechanisms, which may explain the observed diversity of exoplanetary orbits. We conclude that sophisticated models of the inner unresolved disk regions should be used when modeling the formation and evolution of gaseous and dusty protoplanetary disks.

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The effects of ionization feedback on star formation: A case study of the M16 HII region

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We aim to investigate the impact of the ionized radiation from the M16 HII region on the surrounding molecular cloud and on its hosted star formation. To present comprehensive multi-wavelength observations towards the M16 HII region, we used new CO data and existing infrared, optical, and submillimeter data. The $^{12}\text{CO } J=1-0$, $^{13}\text{CO } J=1-0$, and $\text{C}^{18}\text{O } J=1-0$ data were obtained with the Purple Mountain Observatory (PMO) 13.7m radio telescope. To trace massive clumps and extract young stellar objects (YSOs) associated with the M16 HII region, we used the ATLASGAL and GLIMPSE I catalogs, respectively. From CO data, we discern a large-scale filament with three velocity components. Because these three components overlap with each other in both velocity and space, the filament may be made of three layers. The M16 ionized gas interacts with the large-scale filament and has reshaped its structure. In the large-scale filament, we find 51 compact cores from the ATLASGAL catalog, 20 of them being quiescent. The mean excitation temperature of these cores is 22.5 K, while this is 22.2 K for the quiescent cores. This high temperature observed for the quiescent cores suggests that the cores may be heated by M16 and do not experience internal heating from sources in the cores. Through the relationship between the mass and radius of these cores, we obtain that 45% of all the cores are massive enough to potentially form massive stars. Compared with the thermal motion, the turbulence created by the nonthermal motion is responsible for the core formation. For the pillars observed towards M16, the H II region may give rise to the strong turbulence.

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<http://arxiv.org/pdf/1905.08030>

On the formation of density filaments in the turbulent interstellar medium

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This study is motivated by recent observations on ubiquitous interstellar density filaments and guided by modern theories of compressible magnetohydrodynamic (MHD) turbulence. The interstellar turbulence shapes the observed density structures. As the fundamental dynamics of compressible MHD turbulence, perpendicular turbulent mixing of density fluctuations entails elongated density structures aligned with the local magnetic field, accounting for low-density parallel filaments seen in diffuse atomic and molecular gas. The elongation of low-density parallel filaments depends on the turbulence anisotropy. When taking into account the partial ionization, we find that the minimum width of parallel filaments in the cold neutral medium and molecular clouds is determined by the neutral-ion decoupling scale perpendicular to magnetic field. In highly supersonic MHD turbulence in molecular clouds, both low-density parallel filaments due to anisotropic turbulent mixing and high-density filaments due to shock compression exist.

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ALMA Observations of Layered Structures due to CO Selective Dissociation in the ρ Ophiuchi A Plane-parallel PDR

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We analyze $^{12}\text{CO}(J=2-1)$, $^{13}\text{CO}(J=2-1)$, $\text{C}^{18}\text{O}(J=2-1)$, and 1.3 mm continuum maps of the ρ Ophiuchi A photo-dissociation region (PDR) obtained with ALMA. Layered structures of the three CO isotopologues with an angular separation of $10'' = 6.6 \times 10^{-3} \text{ pc} = 1400 \text{ au}$ are clearly detected around the Be star, S1 (i.e., each front of emission shifts from the near to far side in order of ^{12}CO , ^{13}CO , and C^{18}O). We estimate the spatial variations of $X(^{13}\text{CO})/X(\text{C}^{18}\text{O})$ abundance ratios, and find that the abundance ratio is as high as 40 near the emission front, and decreases to the typical value in the solar system of 5.5 in a small angular scale of $4'' = 2.6 \times 10^{-3} \text{ pc} = 560 \text{ au}$. We also find that the $I(^{12}\text{CO}(2-1))/I(^{13}\text{CO}(2-1))$ intensity ratio is very high (>21) in the flat-spectrum young stellar object, GY-51, located in the PDR. The enhancement of the ratios indicates that the UV radiation significantly affects the CO isotopologues via selective dissociation in the overall ρ Ophiuchi A PDR, and that the ρ Ophiuchi A PDR has a plane-parallel structure.

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Synthetic molecular line observations of the first hydrostatic core from chemical calculations

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The first stable object to develop in the low-mass star formation process has long been predicted to be the first hydrostatic core (FHSC). Despite much effort, it has still yet to be definitively observed in nature. More specific observational signatures are required to enable observers to distinguish the FHSC from young, faint, but more evolved protostars. Here we present synthetic spectral line observations for CO, SO, CS and HCO^+ that were calculated from radiation (magneto)hydrodynamical models, chemical modelling and Monte Carlo radiative transfer. $\text{HCO}^+(1-0)$ and $\text{SO}(8_7-7_6)$ spectra of the FHSC show variations for observations at a low inclination which may allow a candidate FHSC to be distinguished from a more evolved object. We find that the FHSC outflow is unlikely to be detectable with ALMA, which would discount the observed sources with slow outflows that are currently identified as candidate FHSCs. We compare the results of simulated ALMA observations with observed candidate FHSCs and recommend Oph A SM1N and N6-mm as the most promising candidates to follow up.

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Sequential Star Formation in the filamentary structures of the Planck Galactic cold clump G181.84+0.31

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We present a multi-wavelength study of the Planck cold clump G181.84+0.31, which is located at the northern end of the extended filamentary structure S242. We have extracted 9 compact dense cores from the SCUBA-2 850 μ m map, and we have identified 18 young stellar objects (YSOs, 4 Class I and 14 Class II) based on their Spitzer, Wide-field Infrared Survey Explorer (WISE) and Two-Micron All-Sky Survey (2MASS) near- and mid-infrared colours. The dense cores and YSOs are mainly distributed along the filamentary structures of G181.84 and are well traced by HCO⁺(1-0) and N₂H⁺(1-0) spectral-line emission. We find signatures of sequential star formation activities in G181.84: dense cores and YSOs located in the northern and southern sub-structures are younger than those in the central region. We also detect global velocity gradients of about 0.8 ± 0.05 km s⁻¹ pc⁻¹ and 1.0 ± 0.05 km s⁻¹ pc⁻¹ along the northern and southern sub-structures, respectively, and local velocity gradients of 1.2 ± 0.1 km s⁻¹ pc⁻¹ in the central substructure. These results may be due to the fact that the global collapse of the extended filamentary structure S242 is driven by an edge effect, for which the filament edges collapse first and then further trigger star formation activities inward. We identify three substructures in G181.84 and estimate their critical masses per unit length, which are $\sim 101 \pm 15$ M_⊙ pc⁻¹, 56 ± 8 M_⊙ pc⁻¹ and 28 ± 4 M_⊙ pc⁻¹, respectively. These values are all lower than the observed values (~ 200 M_⊙ pc⁻¹), suggesting that these sub-structures are gravitationally unstable.

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One Solution to the Mass Budget Problem for Planet Formation: Optically Thick Disks with Dust Scattering

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ALMA surveys have suggested that the dust in Class II disks may not be enough to explain the averaged solid mass in exoplanets, under the assumption that the mm disk continuum emission is optically thin. This optically thin assumption seems to be supported by recent DSHARP observations where the measured optical depths of spatially resolved disks are mostly less than one. However, we point out that dust scattering can considerably reduce the emission from an optically thick region. If that scattering is ignored, the optical depth will be considerably underestimated. An optically thick disk with scattering can be misidentified as an optically thin disk. Dust scattering in more inclined

disks can reduce the intensity even further, making the disk look even fainter. The measured optical depth of ~ 0.6 in several DSHARP disks can be naturally explained by optically thick dust with an albedo of ~ 0.9 at 1.25 mm. Using the DSHARP opacity, this albedo corresponds to a dust population with the maximum grain size (s_{max}) of 0.1-1 mm. For optically thick scattering disks, the measured spectral index α can be either larger or smaller than 2 depending on if the dust albedo increases or decreases with wavelength. Using the DSHARP opacity, $\alpha < 2$ corresponds to s_{max} of 0.03-0.3 mm. We describe how this optically thick scattering scenario could explain the observed scaling between submm continuum sizes and luminosities, and might help ease the tension between the dust size constraints from polarization and dust continuum measurements. We suggest that a significant amount of disk mass can be hidden from ALMA observations at short millimeter wavelengths. For compact disks smaller than 30 au, we can easily underestimate the dust mass by more than a factor of 10. Longer wavelength observations (e.g. VLA or SKA) are desired to probe the dust mass in disks.

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<https://arxiv.org/pdf/1904.02127>

Abstracts of recently accepted major reviews

Probing the cold magnetized Universe with SPICA-POL (B-BOP)

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SPICA, the cryogenic infrared space telescope recently pre-selected for a “Phase A” concept study as one of the three remaining candidates for ESA’s fifth medium class (M5) mission, is foreseen to include a far-infrared polarimetric imager (SPICA-POL, now called B-BOP), which would offer a unique opportunity to resolve major issues in our understanding of the nearby, cold magnetized Universe. This paper presents an overview of the main science drivers for B-BOP, including high dynamic range polarimetric imaging of the cold interstellar medium (ISM) in both our Milky Way and nearby galaxies. Thanks to a cooled telescope, B-BOP will deliver wide-field 100–350 μm images of linearly polarized dust emission in Stokes Q and U with a resolution, signal-to-noise ratio, and both intensity and spatial dynamic ranges comparable to those achieved by *Herschel* images of the cold ISM in total intensity (Stokes I). The B-BOP 200 μm images will also have a factor ~ 30 higher resolution than *Planck* polarization data. This will make B-BOP a unique tool for characterizing the statistical properties of the magnetized interstellar medium and probing the role of magnetic fields in the formation and evolution of the interstellar web of dusty molecular filaments giving birth to most stars in our Galaxy. B-BOP will also be a powerful instrument for studying the magnetism of nearby galaxies and testing galactic dynamo models, constraining the physics of dust grain alignment, informing the problem of the interaction of cosmic rays with molecular clouds, tracing magnetic fields in the inner layers of protoplanetary disks, and monitoring accretion bursts in embedded protostars.

Accepted by Publications of the Astronomical Society of Australia (PASA)

<http://arxiv.org/pdf/1905.03520>

Meetings

Whispers special session: Massive data processing and analysis in radioastronomy, Amsterdam, September 26, 2019

First announcement and call for oral contributions and posters, deadline: Friday June 28th in the evening.

Datasets produced by the current and future generations of radio telescopes are becoming extremely large, due to the increase in sensitivity, instantaneous bandpass per pixel and number of pixels per receiver. This is true for the (sub)millimeter domain where the main instruments (IRAM-30m, NOEMA, ALMA, APEX, LMT, etc) now routinely process several tens of GHz with spectral resolutions of the order of 100 kHz (implying the measurements of about 500,000 frequencies simultaneously), as well as for the centimeter domain (VLA, FAST, LOFAR) and the foreseen SKA that will again represent a revolution in data rate. Data processing and analysis of these large volumes require the development of innovative methods based on the most recent advances in signal processing.

To get the best out of such powerful telescopes, and answer key questions on a wide range of astrophysical topics (from the origin of stars and planets, to cosmic dawn), requires to build bridges between the astronomy community and the applied mathematics / signal processing communities. The proposed one-day session during the Whispers (Workshop on Hyperspectral Image and Signal Processing: Evolutions in Remote Sensing) workshop in Amsterdam aims at presenting the challenges encountered by the radio-astronomy community and the on-going activities to solve them. This event will be organized in 3 to 4 sessions of four to five 20-minutes contributed talks introduced by two invited presentations to set the field by

- Anna Scaife (Manchester, UK): Radioastronomy challenges in cosmology and galaxy evolution studies
- Susan Clark (Princeton, USA): Atomic and molecular line imaging as diagnostics for ISM and star formation

Posters will be presented during a flash session. The day will end with a round table to define directions for future collaborations. This table will be animated by Cyril Tasse (Obs. de Paris, France), Yves Wiaux (Heriot-Watt, UK, TBC), and the SOC members.

The themes of the workshop include

- Single dish and interferometer data processing
- Filtering of artifacts and denoising
- Structure identification with or without velocity information
- Clustering
- Identification and quantification of temporal variations
- Data - model comparisons

The astrophysics focus is put on the topics benefiting from advanced radioastronomy observations:

- The relationship between interstellar medium properties and star formation, from the local universe to distant galaxies.
- Observational constraints on Cosmic dawn and the epoch of reionization.

Registration is mandatory, with a reduced fee (190 euros) for the one day special session. The fee includes lunch and coffee breaks. Participants are invited to register and submit either an abstract, an already published paper, or an original paper for publication in IEEE.

Key dates:

Submission deadline 28 June 2019 (This is the actual deadline for this special session. Please disregard the website deadline.)

Final program 15 July 2019.

End of registration 10 September 2019.

Special session 26 September 2019.

SOC:

Jérôme Bobin (CEA Saclay - IRFU/CosmoStat, France), Chiara Ferrari (Observatoire de la Côte d'Azur, France), Maryvonne Gerin (Observatoire de Paris, France), Ralf Klessen (Heidelberg University, Germany), Joshua E. G. Peek (Space Telescope Science Institute & Johns Hopkins University, USA), Jérôme Pety (IRAM & Observatoire de Paris, France)

All information can be found here

<http://www.ieee-whispers.com>

The submission facility is available here

<http://www.ieee-whispers.com/paper-submission/>

You have to create a login account and then submit an abstract. Please select the right session: "Massive data processing and analysis in radioastronomy".

Mission to the Universe From Earth to Planets, Stars & Galaxies -The 2019 Annual Meeting of the German Astronomical Society

16-20 September 2019 in Stuttgart, Germany
will take place
the 2019 Annual Meeting of the German Astronomical Society.

This year, it's titled:

Mission to the Universe

From Earth to Planets, Stars & Galaxies

"It's a German version of AAS meeting",
with different plenary talks and splinter sessions;
plus this year Stratospheric Observatory for Infrared Astronomy (SOFIA) will visit us,
and tours for the participants will be provided.

please check the conference website:

<https://conference.dsi.uni-stuttgart.de/e/ag2019>

and hopefully, see you in Stuttgart!

Summary of Upcoming Meetings

From Stars to Planets II: Connecting our Understanding of Star and Planet Formation

17 - 20 June 2019, Gothenburg, Sweden

<http://cosmicorigins.space/fstpii>

Gaia's View of Pre-Main Sequence Evolution. Linking the T Tauri and Herbig Ae/Be Stars

18 - 21 June 2019, Leeds, UK

<https://starry-project.eu/final-conference>

Gordon Conference on Origins of Solar Systems: Meteoritical, Spacecraft and Astrophysical Perspectives on the Assembly and Composition of Planets

23 - 28 June 2019

<https://www.grc.org/origins-of-solar-systems-conference/2019/>

Astrochemistry: From nanometers to megaparsecs - A Symposium in Honour of John H. Black

24 - 28 June 2019, Gothenburg, Sweden

<https://www.chalmers.se/en/conference/JHBlacksymp2019/>

Smoothed Particle Hydrodynamics International Workshop

25 - 27 June 2019, Exeter, UK

<http://spheric2019.co.uk/>

Great Barriers in Planet Formation

21 - 26 July 2019 Palm Cove, Australia

<https://dustbusters.bitbucket.io/great-barriers-2019/>

Summer School Protoplanetary Disks and Planet Formation

5 - 9 August 2019 Copenhagen, Denmark

<http://nbia.nbi.ku.dk/nbia-school-2019>

Orion Uncovered

26 - 30 August 2019 Leiden, The Netherlands

<https://sites.google.com/view/OrionLeiden2019>

Understanding the Nearby Star-forming Universe with JWST

26 - 30 Aug 2019 Courmayeur, Italy

<http://www.stsci.edu/institute/conference/unsfjwst2019>

Celebrating the first 40 Years of Alexander Tielens' Contribution to Science: The Physics and Chemistry of the ISM

2 - 6 september 2019, Avignon, France <https://tielens2019.sciencesconf.org>

From Gas to Stars: The Links between Massive Star and Star Cluster Formation

16-20 September 2019 York, UK

<https://starformmapper.org/final-conference/>

Crete III - Through dark lanes to new stars Celebrating the career of Prof. Charles Lada

23 - 27 September 2019 Crete, Greece

<http://crete3.org>

The UX Ori type stars and related topics

30 September - 4 October 2019 St. Petersburg, Russia

<http://uxors-2019.craocrimea.ru>

First Stars VI

1 - 6 March 2020 Concepcion, Chile

<http://www.astro.udec.cl/FirstStarsVI/>

Linking Dust, Ice, and Gas in Space

19 - 24 April 2020, Capri, Italy

<http://frcongressi.net/ecla2020.meet>

COOL STARS 21: Cambridge Workshop on Cool Stars, Stellar Systems and the Sun

21 -26 June 2020, Toulouse, France

<https://coolstars21.github.io/>

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

29 June - 3 July 2020 Lyon, France <https://cral.univ-lyon1.fr>

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.