THE STAR FORMATION NEWSLETTER

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

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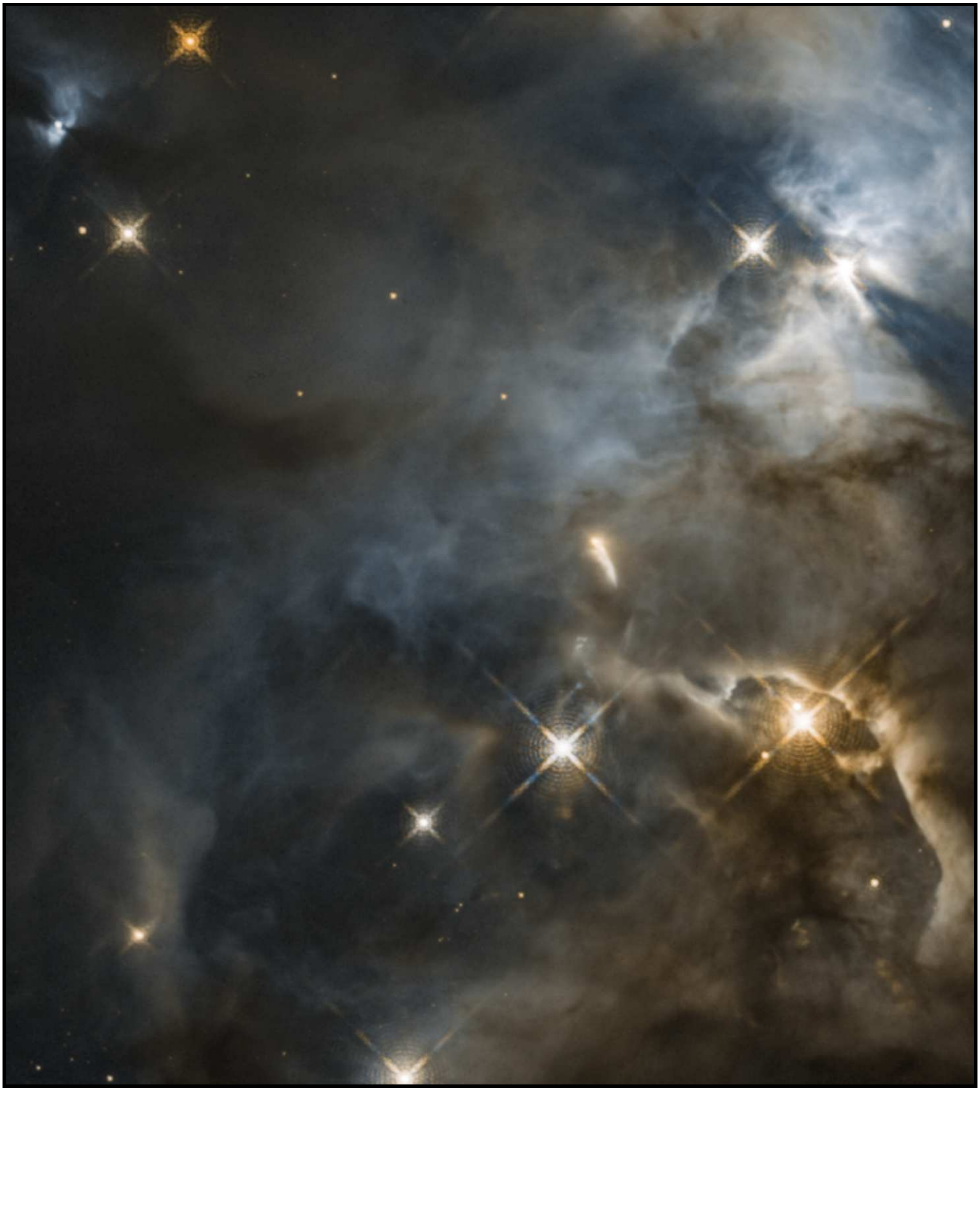

The Star Formation Newsletter

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

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Cover Picture

The cover shows a region of the Serpens star forming cloud as imaged by HST. A disk around the young star HBC 672 = EC82 (to the upper right) casts a large shadow over its surroundings. See the abstract by Pontoppidan et al. in this issue.

Image courtesy NASA, ESA, and Klaus Pontoppidan (STScI).

Submitting your abstracts

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

Immo Appenzeller

in conversation with Bo Reipurth

Q: *First of all, congratulations on your 80th birthday. You have witnessed essentially the whole development of the subject of star formation. How did your own involvement with the subject start?*

A: Thanks, Bo, for the congratulations and for inviting me to your interview series. To your question: I got involved in star formation as a by-product of work on quasars. I had studied physics at the universities of Tübingen and Göttingen. After graduating in 1966 with a thesis on the the local interstellar magnetic field, as traced by the interstellar polarization, I spent some time at the University of Chicago. There I built a new and more sensitive polarimeter, which I used at the telescopes of the McDonald Observatory in Texas. Among my targets were the newly discovered quasars, which were the most discussed objects of that time. To test one of the mechanisms, which had been proposed to explain quasars, I carried out numerical model computations, and as a by-product I obtained a computer code that was suitable for simulating star formation.

Q: *Could you explain this in more detail? Why did you switch to theory and how did this lead to your investigations of massive protostars? And what were your conclusions?*

A: My initial aim was to investigate a quasar model, which had been proposed in 1966 by William Fowler. He had suggested that quasars resulted from relaxation oscillations of unstable supermassive ($M \geq 10^5 M_\odot$) stars. To test this scenario I planned numerical simulations using the stellar evolution code of Rudolf Kippenhahn. Kippenhahn had started developing this code at the Max-Planck-Institute for Astrophysics in Munich, but in 1965 he had moved to Göttingen, where he formed a new group for theoretical astrophysics. To earn money, I had done some programming for his group while working on my thesis. Therefore, I was familiar with Kippenhahn's code, and when I returned to Germany in the second half of 1967, I joined his theory group. Kippenhahn's code was hydrostatic and Newtonian, but the quasar model required a dynamical and relativistic code. Therefore, I modified Kippenhahn's code in two steps: First I replaced the hydrostatic equation with a Newtonian equation of motion. After the resulting Newtonian dynamical code was running, I replaced the Newtonian equations by the corresponding relativistic equations. The numerical results showed that Fowler's quasar model could not explain the quasars. Therefore, I retired the relativistic code and applied the Newtonian version to various problems of stellar physics, including star formation via the contraction and collapse of interstellar gas clouds. A few years earlier Richard Larson and others had demonstrated that the outcome of such computations was a 'protostar', consisting of a hydrostatic core, which was accreting matter from an extended envelope. Simulations, carried out together with Werner Tscharnuter, confirmed this result for different parameters and different initial conditions. As our code included the energy production by nuclear reactions, we could simulate the evolution of more massive protostars, where the hydrostatic evolutionary time scale of the core becomes shorter than the accretion time scale. For an initially 60 $M_\odot$ protostar we found that the mass accretion was halted and the remaining envelope was blown away, soon after hydrogen burning had started in the core. Our code did not include rotation, but we expected that with rotation the outcome would have been qualitatively similar.

Q: *You then returned to observations and wrote a series of papers on the so-called YY Orionis-type stars, like S CrA and RW Aur.*

A: I enjoyed doing theoretical work in Kippenhan's group, but I never completely abandoned observational astronomy. When ESO's La Silla Observatory in Chile was officially opened in 1969, I started using the first small telescopes there. With larger telescopes under construction at ESO and the creation of the German-Spanish Astronomical Center on Calar Alto in Spain, observational astronomy became attractive again in Germany. Thus, when I was offered a professorship at the University of Heidelberg in 1975, I accepted with the aim of forming a research group, which combined theory and observations. One of our first programs in Heidelberg was identifying observational counterparts of the predicted protostars. Among the prime candidates were the T Tauri stars. They were known to be young, and they showed chromospheric emission spectra which resembled those predicted for the cooling zones of protostellar accretion shocks. Already in 1948 Jesse Greenstein had suggested that the properties of the T Tauri stars resulted from mass infall on forming stars. This suggestion was supported by Merle Walker, who in

1972 identified a subclass of the T Tauri stars, which he called 'YY Ori stars', and which were characterized by a strong UV excess at the U band and redward displaced absorption components at the higher Balmer lines. The observed velocity shifts were close to the expected free-fall velocities of low-mass PMS stars. To investigate the suggested protostellar nature of the T Tauri stars, we combined non-LTE line profile calculations, done mainly by Claude Bertout and Ulrich Bastian, with spectroscopic observations, carried out by Claude Bertout, Bernhard Wolf, Joachim Krautter, Reinhard Mundt, Carlos Chavarria, and others. We found signs for mass accretion in the spectra of most classical T Tau stars and redward displaced absorption at many different spectral lines.

Q: *You were among the first to explore the ultraviolet spectrum of young stars using the newly launched IUE satellite. What did you learn?*

A: In addition to a chromospheric line spectrum, protostars were predicted to emit a strong UV flux originating in the accretion shocks. Indications that this was actually observed, were the UV excess at the U band, and the increase of the flux between the U band and the atmospheric cutoff, which was seen on spectrograms observed by Merle Walker with a Lallemand camera. The launch of the IUE satellite provided a chance to measure the extent and shape of the UV continuum and to derive its contribution to the total luminosity. Therefore, as soon as IUE became operational, we applied for observing time. For S CrA, the at that time brightest known YY Ori star, we combined the IUE data with groundbased IR photometry to derive the continuum between 15 nm and 22 μm. The observed UV continuum, corrected for interstellar absorption, was found to peak near 200 nm. Only a minor fraction of the total luminosity of S CrA was found to originate from the stellar photosphere. Among the other observed T Tau stars, the results for GQ Lup (at that time known as CoD -35 10525) and for DR Tau were particularly interesting. GQ Lup has a typical YY Ori spectrum, with photospheric absorption lines corresponding to a spectral type K7 and clearly visible redward displaced absorption components at the higher Balmer lines. But its UV flux was found to be much weaker than in S CrA. On the other hand, DR Tau, which often has only week redward displaced absorption features, was found to emit a UV flux even larger than that of S CrA. This confirmed earlier indications that the strength of the Balmer continuum and of the Balmer emission lines are the most reliable measures of the mass accretion. Compared to the visual spectra, the UV emission line spectra were found to vary more strongly between the individual T Tauri stars.

Q: *In the winter of 1981 you and your collaborators took advantage of the long nights in northern Norway to spectroscopically monitor T Tauri stars, especially RW Aur.*

A: This was a joint project with an astronomy group, which at that time existed at the Norwegian University of Tromsø. Tromsø is located about 350 km north of the Arctic Circle. Thus, at midwinter the sun remains below the horizon for about 50 days, and the sky remains dark for about three weeks. Tromsø itself is not a suitable observatory site, as the winters bring fog, clouds, and heavy snowfall. But its University operated a 50 cm Telescope about 50 km east of Tromsø, in the Skibotn valley, which belongs to the places with the highest percentage of clear sky in Norway. As the Skibotn telescope did not have spectroscopic equipment, we brought a fiber-coupled spectrometer with a two-stage image tube from Heidelberg. The observations were carried out jointly by students and staff from Tromsø and Heidelberg. As you mentioned, the main target was the YY Ori star RW Aur, which could be observed, with minor interruptions, for about 12 days. Our results disagreed with most of the mechanisms which had been suggested for the irregular spectral variations of RW Aur, but they were consistent with the assumption of variable mass accretion being the main cause of the variations.

Q: *In 1983, you and David Dearborn used models of variable surface magnetic fields in T Tauri stars for comparison with their observed photometric observations. What resulted from this study?*

A: I met Dave during the winter 1982/1983, when I spent part of a sabbatical in Tucson. When I learned about Dave's stellar evolution code, which included the effects of star spots produced by magnetic fields, I proposed to apply this code to PMS stars. The presence of star spots in PMS and T Tauri stars had been suggested by many different authors to explain the irregular as well as the rotation-related cyclic light variations. We calculated a series of models, with different initial conditions and values of the total surface magnetic flux between zero and the maximum value consistent with an equilibrium of the gas and the magnetic pressures at the surface. For all models we derived the V-magnitude change, the total spot area, and the effective temperatures of the spots and of the spot-free surface area. As a result we found that in purely hydrostatic PMS stars the spots could cause irregular V-magnitude variations up to about 3.5 mag and cyclic variations up to about 2.2 mag. If accretion shocks contribute to the continuum at the V band, these upper limits are somewhat lower. Nevertheless, we concluded that all observed cyclic variations and part of the observed irregular variations could, in principle, be explained by star spots. But for YY Ori stars with larger irregular variations (such as DR Tau) variable mass accretion remained the only viable explanation. Other conclusions were that the observed effective temperature depends on the relative contribution of the spots to the total surface, and that spectral types derived from the photospheric absorption lines depend on the spectral range observed. This, and the contribution of shock emission to the luminosity, has to be taken into account, when trying to place T Tauri stars in an HR diagram. Finally, we found the reduction of the photospheric emission by the spots to increase the hydrostatic evolutionary time scale during the fully convective PMS phase.

Q: *In the late 1980s you led a series of studies of the absorption and emission line spectra of T Tauri stars using high-resolution echelle spectra.*

A: At the beginning of the 1980s, the more sensitive and linear CCDs replaced photographic plates and image tubes. This resulted in an improved flux calibration and a better sky background subtraction. And it became possible to subtract the photospheric spectra from the emission lines (and vice versa) more accurately. As CCDs could not be fitted well to the coudé spectrographs of that time, echelle spectrometers became the main instruments for high resolution spectroscopy. We used these new instrumental capabilities to study the T Tauri spectra with higher spectral resolution and better S/N. And by accurately subtracting the photospheric spectra, we could derive the true line profiles of the infalling matter. Among the new results was the detection of the systematic blueshift of the forbidden emission lines. As such lines had been observed to originate in bipolar outflows and jets from young stars, we suggested that the systematic blueshift resulted from the fact that only the jet flows directed towards us could be observed, while the receding counter jets were hidden by an opaque accretion disk. Accretion disks had been predicted theoretically and inferred from the IR spectra of young stars, but they had not yet been observed directly. The simultaneous presence of accretion disks and infall with nearly free-fall velocities resulted in the current magnetospheric model of the T Tauri stars, where matter in the disk is slowly moving inward, until the radius of co-rotation between the disk and the stellar surface is reached. Inside this radius the model assumes the matter to be in free fall along magnetic field lines, until stopped at the accretion shock. The magnetic fields also explained the removal of angular momentum and the jets. Although I continued to follow the progress in star formation with great interest, after 1990 I devoted most of my time (again) to quasars, AGN, and hot stars, were progress in X-ray astronomy and far and extreme UV spectroscopy lead to new opportunities. And when ESO's VLT became operational, distant extragalactic objects became my favorite subjects.

Q: *Most recently you and Claude Bertout have studied inclination effects in T Tauri spectra. What were your conclusions?*

A: Although my main activities were in other fields, occasionally I still tried to contribute a bit to star formation. An example is the paper on inclination effects with Claude Bertout. The presence of rotation, disks, and jets make the T Tauri systems, on first approximation, rotationally symmetric. Therefore, a dependence of their observed appearance on the angle between the symmetry axis and the line of sight had been suggested. Earlier searches for this effect failed, as the inclination angles could not be derived with sufficient accuracy. Claude and I started a new attempt, when images of T Tauri disks, resolved by optical, IR and mm-wave interferometry, became available. Assuming that the disks are intrinsically circular, and that the disk axes are the system axes, we used the oblateness of the disk images to derive the inclination. A clear inclination dependence was found for the velocities of the forbidden lines, for the wind absorption components of the Balmer lines and for the properties of the Helium lines. And, knowing the inclination, we could derive the true, deprojected flow velocities of the jets.

Q: *During the more than half century of research that you have witnessed, star formation studies have developed from a quiet backwater to one of the main pillars of astrophysics. What are your views on the role of technology in this amazing progress?*

A: Technological advances always played a decisive role for progress in astronomy. Most important for star formation was probably the invention and the development of computers. In the older literature on star formation, one finds plenty of ideas and interesting speculations. Some of these ideas, such as Greenstein's T Tauri scenario, were even correct. But, as experiments are rarely possible in astrophysics, reliable tests of such ideas became feasible only after physical processes could be simulated numerically. Computers also play a pivotal role for today's detectors and receivers. CCDs, which initially were developed as shift registers for computers, require computer hardware for the readout and the image reconstruction. Many techniques used for star formation studies, such as active and adaptive optics, and interferometric imaging, had been proposed a long time ago, but could be realized only after the required computing power became available. The important role of improved detectors has already been mentioned. Other technical advances enabling progress in star formation, were astronomy from space and from airplanes, and the improvements in the telescope and interferometer technologies. Following these technological advances and the resulting scientific progress over half a century was highly interesting, and a great pleasure.

Abstracts of recently accepted papers

Chemical Variation among Protostellar Cores: Dependence on Prestellar Core Conditions

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Hot corino chemistry and warm carbon chain chemistry (WCCC) are driven by gas-grain interactions in star-forming cores: radical-radical recombination reactions to form complex organic molecules (COMs) in the ice mantle, sublimation of CH_4 and COMs, and their subsequent gas-phase reactions. These chemical features are expected to depend on the composition of ice mantle which is set in the prestellar phase. We calculated the gas-grain chemical reaction network considering a layered ice-mantle structure in star-forming cores, to investigate how the hot corino chemistry and WCCC depend on the physical condition of the static phase before the onset of gravitational collapse. We found that WCCC becomes more active, if the temperature is lower, or the visual extinction is lower in the static phase, or the static phase is longer. Dependence of hot corino chemistry on the static-phase condition is more complex. While CH_3OH is less abundant in the models with warmer static phase, some COMs are formed efficiently in those warm models, since there are various formation paths of COMs. If the visual extinction is lower, photolysis makes COMs less abundant in the static phase. Once the collapse starts and visual extinction increases, however, COMs can be formed efficiently. Duration of the static phase does not largely affect COM abundances. Chemical diversity between prototypical hot corinos and hybrid sources, in which both COMs and carbon chains are reasonably abundant, can be explained by the variation of prestellar conditions. Deficiency of gaseous COMs in prototypical WCCC sources is, however, hard to reproduce within our models.

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http://arxiv.org/pdf/2006.11696

Three generations of stars: a possible case of triggered star formation

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Evidence for triggered star formation linking three generations of stars is difficult to assemble, as it requires convincingly associating evolved massive stars with HII regions that, in turn, would need to present signs of active star formation. We present observational evidence for triggered star formation relating three generations of stars in the neighbourhood of the star LS II +26 8. We carried out new spectroscopic observations of LS II +26 8, revealing that it is a B0 III-type star. We note that LS II +26 8 is located exactly at the geometric centre of a semi-shell-like HII region complex. The most conspicuous component of this complex is the HII region Sh2-90, which is probably triggering a new generation of stars. The distances to LS II +26 8 and to Sh2-90 are in agreement (between 2.6 and 3 kpc). Analysis of the interstellar medium on a larger spatial scale shows that HII region complex lies on the northwestern border of an extended H_2 shell. The radius of this molecular shell is about 13 pc, which is in agreement with what an O9V star (the probable initial spectral type of LS II +26 8 as inferred from evolutive tracks) can generate through its winds in the molecular environment. In conclusion, the spatial and temporal correspondences derived in our analysis enable us to propose a probable triggered star formation scenario initiated by the evolved massive star LS II +26 8 during its

main sequence stage, followed by stars exciting the HII region complex formed in the molecular shell, and culminating in the birth of YSOs around Sh2-90.

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An evolutionary study of volatile chemistry in protoplanetary disks

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The volatile composition of a planet is determined by the inventory of gas and ice in the parent disk. The volatile chemistry in the disk is expected to evolve over time, though this evolution is poorly constrained observationally. We present ALMA observations of $C^{18}O$, C_2H, and the isotopologues $H^{13}CN$, $HC^{15}N$, and DCN towards five Class 0/I disk candidates. Combined with a sample of fourteen Class II disks presented in Bergner et al. (2019b), this data set offers a view of volatile chemical evolution over the disk lifetime. Our estimates of $C^{18}O$ abundances are consistent with a rapid depletion of CO in the first ∼0.5–1 Myr of the disk lifetime. We do not see evidence that C_2H and HCN formation are enhanced by CO depletion, possibly because the gas is already quite under-abundant in CO. Further CO depletion may actually hinder their production by limiting the gas-phase carbon supply. The embedded sources show several chemical differences compared to the Class II stage, which seem to arise from shielding of radiation by the envelope (impacting C_2H formation and $HC^{15}N$ fractionation) and sublimation of ices from infalling material (impacting HCN and $C^{18}O$ abundances). Such chemical differences between Class 0/I and Class II sources may affect the volatile composition of planet-forming material at different stages in the disk lifetime.

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Star-forming sites IC 446 and IC 447: an outcome of end-dominated collapse of Monoceros R1 filament

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We present an analysis of multi-wavelength observations of Monoceros R1 (Mon R1) complex (at d ∼760 pc). An elongated filament (length ∼14 pc, mass ∼1465 $M_\odot$) is investigated in the complex, which is the most prominent structure in the *Herschel* column density map. An analysis of the FUGIN $^{12}CO(1–0)$ and $^{13}CO(1–0)$ line data confirms the existence of the filament traced in a velocity range of $[-5, +1]$ km s^{-1}. The filament is found to host two previously known sites IC 446 and IC 447 at its opposite ends. A massive young stellar object (YSO) is embedded in IC 446, while IC 447 contains several massive B-type stars. The *Herschel* temperature map reveals the extended warm dust emission (at $T_d \sim$ 15–21 K) toward both the ends of the filament. The *Spitzer* ratio map of 4.5 μm/3.6 μm emission suggests the presence of photo-dissociation regions and signature of outflow activity toward IC 446 and IC 447. Based on the photometric analysis of point-like sources, clusters of YSOs are traced mainly toward the filament ends. The filament is found to be thermally supercritical showing its tendency of fragmentation, which is further confirmed by the detection of a periodic oscillatory pattern (having a period of ∼3–4 pc) in the velocity profile of ^{13}CO. Our outcomes suggest that the fragments distributed toward the filament ends have rapidly collapsed, and had formed the known star-forming sites. Overall, the elongated filament in Mon R1 is a promising sample of the

"end-dominated collapse" scenario, as discussed by Pon et al. (2011, 2012).

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https://arxiv.org/pdf/2006.13894.pdf

Shape Analysis of HII Regions – II. Synthetic Observations

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The statistical shape analysis method developed for probing the link between physical parameters and morphologies of Galactic HII regions is applied here to a set of synthetic observations (SOs) of a numerically modelled HII region. The systematic extraction of HII region shape, presented in the first paper of this series, allows for a quantifiable confirmation of the accuracy of the numerical simulation, with respect to the real observational counterparts of the resulting SOs. A further aim of this investigation is to determine whether such SOs can be used for direct interpretation of the observational data, in a future supervised classification scheme based upon HII region shape. The numerical HII region data was the result of photoionisation and radiation pressure feedback of a 34 $M_\odot$ star, in a 1000 $M_\odot$ cloud. The SOs analysed herein comprised four evolutionary snapshots (0.1, 0.2, 0.4 and 0.6 Myr), and multiple viewing projection angles. The shape analysis results provided conclusive evidence of the efficacy of the numerical simulations. When comparing the shapes of the synthetic regions to their observational counterparts, the SOs were grouped in amongst the Galactic HII regions by the hierarchical clustering procedure. There was also an association between the evolutionary distribution of regions and the respective groups. This suggested that the shape analysis method could be further developed for morphological classification of HII regions by using a synthetic data training set, with differing initial conditions of well-defined parameters.

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The distances to molecular clouds in the fourth Galactic quadrant

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Distance measurements to molecular clouds are essential and important. We present directly measured distances to 169 molecular clouds in the fourth quadrant of the Milky Way. Based on the near-infrared photometry from the Two Micron All Sky Survey and the Vista Variables in the Via Lactea Survey, we select red clump stars in the overlapping directions of the individual molecular clouds and infer the bin averaged extinction values and distances to these stars. We track the extinction versus distance profiles of the sightlines toward the clouds and fit them with Gaussian dust distribution models to find the distances to the clouds. We have obtained distances to 169 molecular clouds selected from Rice et al. The clouds range in distances between 2 and 11 kpc from the Sun. The typical internal uncertainties in the distances are less than 5 per cent and the systematic uncertainty is about 7 per cent. The catalogue presented in this work is one of the largest homogeneous catalogues of distant molecular clouds with the direct measurement of distances. Based on the catalogue, we have tested different spiral arm models from the literature.

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Evolutionary study of complex organic molecules in high-mass star-forming regions

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We have studied four complex organic molecules (COMs), the oxygen-bearing methyl formate (CH_3OCHO) and dimethyl ether (CH_3OCH_3) as well as the nitrogen-bearing formamide (NH_2CHO) and ethyl cyanide (C_2H_5CN), towards a large sample of 39 high-mass star-forming regions representing different evolutionary stages, from early to evolved phases. We aim to identify potential correlations and chemical links between the molecules and to trace their evolutionary sequence through the star formation process.
We analysed spectra obtained at 3, 2, and 0.9 mm with the IRAM-30m telescope. We derived the main physical parameters for each species by fitting the molecular lines. We compared them and evaluated their evolution while also taking several other interstellar environments into account.
We report detections in 20 sources, revealing a clear dust absorption effect on column densities. Derived abundances range between $\sim 10^{-10} - 10^{-7}$ for CH_3OCHO and CH_3OCH_3, $\sim 10^{-12} - 10^{-10}$ for NH_2CHO, and $\sim 10^{-11} - 10^{-9}$ for C_2H_5CN. The abundances of CH_3OCHO, CH_3OCH_3, and C_2H_5CN are very strongly correlated ($r \geq 0.92$) across $\sim$4 orders of magnitude. We note that CH_3OCHO and CH_3OCH_3 show the strongest correlations in most parameters, and a nearly constant ratio ($\sim$1) over a remarkable $\sim$9 orders of magnitude in luminosity for the following wide variety of sources: pre-stellar to evolved cores, low- to high-mass objects, shocks, Galactic clouds, and comets. This indicates that COMs chemistry is likely early developed and then preserved through evolved phases. Moreover, the molecular abundances clearly increase with evolution, covering $\sim$6 orders of magnitude in the luminosity/mass ratio.
We consider CH_3OCHO and CH_3OCH_3 to be most likely chemically linked. They could, for example, share a common precursor, or be formed one from the other. Based on correlations, ratios, and the evolutionary trend, we propose a general scenario for all COMs, involving a formation in the cold, earliest phases of star formation and a following increasing desorption with the progressive thermal and shock-induced heating of the evolving core.

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Carbon isotopic fractionation in molecular clouds

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C-fractionation has been studied from a theoretical point of view with different models of time-dependent chemistry, including both isotope-selective photodissociation and low-temperature isotopic exchange reactions. Recent chemical models predict that the latter may lead to a depletion of ^{13}C in nitrile-bearing species, with $^{12}C/^{13}C$ ratios two times higher than the elemental abundance ratio of 68 in the local interstellar medium. Since the carbon isotopic ratio is commonly used to evaluate the $^{14}N/^{15}N$ ratios with the double-isotope method, it is important to study carbon fractionation in detail to avoid incorrect assumptions. In this work we implemented a gas-grain chemical model with new isotopic exchange reactions and investigated their introduction in the context of dense and cold molecular gas. In particular, we investigated the $^{12}C/^{13}C$ ratios of HNC, HCN, and CN using a grid of models, with temperatures and densities ranging from 10 to 50 K and 2×10^3 to 2×10^7 cm^{-3}, respectively.
We suggest a possible ^{13}C exchange through the $^{13}C + C_3 \rightarrow {}^{12}C + {}^{13}CC_2$ reaction, which does not result in dilution, but rather in ^{13}C enhancement, for molecules that are formed starting from atomic carbon. This effect is efficient in a range of time between the formation of CO and its freeze-out on grains. Furthermore, the parameter-space exploration shows, on average, that the $^{12}C/^{13}C$ ratios of nitriles are predicted to be a factor 0.8–1.9 different from the local $^{12}C/^{13}C$ of 68 for high-mass star-forming regions. This result also affects the $^{14}N/^{15}N$ ratio: a value of 330

obtained with the double-isotope method is predicted to vary in the range 260–630, up to 1150, depending on the physical conditions. Finally, we studied the $^{12}C/^{13}C$ ratios of nitriles by varying the cosmic-ray ionization rate, ζ: the $^{12}C/^{13}C$ ratios increase with ζ because of secondary photons and cosmic-ray reactions.

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Seeds of Life in Space (SOLIS). X. Interstellar Complex Organic Molecules in the NGC 1333 IRAS 4A outflows

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Context. The interstellar Complex Organic Molecules (iCOMs) are C-bearing molecules containing at least six atoms; two main approaches of their formation are invoked: a direct formation in the icy mantle of the dust grains, or through the reaction in gas phase of released grain mantle species. The shocked gas along outflows driven by low-mass protostars is a unique environment to study how the iCOMs can be formed, as the composition of the dust mantles is sputtered into the gas phase.
Aims. The chemical richness in shocked material associated with low-mass protostellar outflows has been so far studied in the prototypical L1157 blue shifted outflow to investigate the iCOMs formation routes. To understand whether the case of L1157-B1 is unique, we imaged and studied the IRAS 4A outflows in the NGC 1333 star forming region.
Methods. We used the NOEMA (NOrthern Extended Millimeter Array) interferometer as part of the IRAM SOLIS (Seeds Of Life in Space) Large Program to image the large scale bipolar outflows driven by the IRAS 4A system in the 3 mm band, and we compared the observation with the GRAINOBLE+ astrochemical model.
Results. We report the first detection, in the IRAS 4A outflows, of several iCOMs: six lines of methanol (CH3OH), eight of acetaldehyde (CH3CHO), one of formamide (NH2CHO) and four of dimethyl ether (CH3OCH3), all sampling upper excitation energy up to ?30 K. We found a significant chemical differentiation between the south east outflow driven by the IRAS 4A1 protostar, showing a richer molecular content, and the north-south west one driven by the IRAS 4A2 hot corino. The CH3OH/CH3CHO abundance ratio is lower by a factor $\sim$4 in the former; furthermore the ratio in the IRAS 4A outflows is lower by a factor $\sim$10 with respect to the values found in different hot corinos.
Conclusions. After L1157-B1, IRAS 4A outflow is now the second outflow to show an evident chemical complexity. Given that CH3OH is a grain surface species, the astrochemical gas phase model run with GRAINOBLE+ reproduced our observation assuming that acetaldehyde is formed mainly through the gas phase reaction of ethyl radical (CH3CH2) and atomic oxygen. Furthermore, the chemical differentiation between the two outflows suggests that the IRAS 4A1 outflow is likely younger than the IRAS 4A2 one.Further investigation is needed to constrain the age of the outflow. In addition, observation of even younger shocks are necessary. In order to provide strong constraints on the CH3CHO formation mechanisms it would be interesting to observe CH3CH2, but given that its frequencies are not known, future spectroscopic studies on this species are needed.

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Hot Corinos Chemical Diversity: Myth or Reality?

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After almost 20 years of hunting, only about a dozen hot corinos, hot regions enriched in interstellar complex organic molecules(iCOMs), are known. Of them, many are binary systems with the two components showing drastically different molecular spectra. Two obvious questions arise. Why are hot corinos so difficult to find and why do their binary components seem chemically different? The answer to both questions could be a high dust opacity that would hide the molecular lines. To test this hypothesis, we observed methanol lines at centimeter wavelengths, where dust opacity is negligible, using the Very Large Array interferometer. We targeted the NGC1333 IRAS 4A binary system, for which one of the two components, 4A1, has a spectrum deprived of iCOMs lines when observed at millimeter wavelengths, while the other component, 4A2, is very rich in iCOMs. We found that centimeter methanol lines are similarly bright toward 4A1 and 4A2. Their non-LTE analysis indicates gas density and temperature($\geq 2 \times 10^6$cm^{-3} and 100-190 K), methanol column density($\sim 10^{19}$cm^{-2}), and extent($\sim$35 au in radius)similar in 4A1 and 4A2, proving that both are hot corinos. Furthermore, the comparison with previous methanol line millimeter observations allows us to estimate the optical depth of the dust in front of 4A1 and 4A2,respectively. The obtained values explain the absence of iCOMs line emission toward 4A1 at millimeter wavelengths and indicate that the abundances toward 4A2 are underestimated by $\sim$30%. Therefore, centimeter observations are crucial for the correct study of hot corinos, their census, and their molecular abundances

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Probing the physical conditions and star formation processes in the Galactic HII region S305

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We present multi-scale and multi-wavelength observations of the Galactic H II region S305, which is excited by massive O8.5V and O9.5V stars. Infrared images reveal an extended sphere-like shell (extension $\sim$7.5 pc; at T_d = 17.5–27 K) enclosing the S305 H II region (size $\sim$5.5 pc; age $\sim$1.7 Myr). The extended structure observed in the *Herschel* temperature map indicates that the molecular environment of S305 is heated by the massive O-type stars. Regularly spaced molecular condensations and dust clumps are investigated toward the edges of the infrared shell, where the PAH and H_2 emission is also observed. The molecular line data show a signature of an expanding shell of molecular gas in S305. GMRT 610 and 1280 MHz continuum maps reveal overdensities of the ionized emission distributed around two O-type stars, which are surrounded by the horseshoe envelope (extension $\sim$2.3 pc). A molecular gas deficient region/cavity is identified toward the center of the horseshoe envelope, which is well traced with PAH, H_2, molecular, and dust emission. The edges of the infrared shell are found to be located in the front of the horseshoe envelope. All these outcomes provide the observational evidence of the feedback of O-type stars in S305. Moreover, non-thermal

radio emission is detected in S305 with an average spectral index $\alpha \sim -0.45$. The variations in α, ranging from -1.1 to 1.3, are explained due to soft synchrotron emission and either optically-thicker thermal emission at high frequencies or a suppression of the low-frequency emission by the Razin-Tsytovich effect.

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Tidal tails of open star clusters as probes to early gas expulsion I: A semi-analytic model

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Star clusters form out of the densest parts of infrared dark clouds. The emergence of massive stars expels the residual gas, which has not formed stars yet. Gas expulsion lowers the gravitational potential of the embedded cluster, unbinding many of the cluster stars. These stars then move on their own trajectories in the external gravitational field of the Galaxy, forming a tidal tail. We investigate the formation and evolution of the tidal tail forming due to expulsion of primordial gas under various scenarios of gas expulsion to provide predictions for tidal tails around dynamically evolved (age $>$ 100 Myr) galactic star clusters, which can be possibly detected by the Gaia mission. We provide a semi-analytical model for the tail evolution. We find that tidal tails released during gas expulsion have different kinematic properties than the tails gradually forming due to evaporation. The gas expulsion tidal tail shows non-monotonic expansion with time, where longer epochs of expansion are interspersed with shorter epochs of contraction. The tail thickness and velocity dispersions strongly, but not exactly periodically, vary with time. The times of minima of tail thickness and velocity dispersions are given only by the properties of the galactic potential, and not by the properties of the cluster. The estimates provided by the (semi-)analytical model for the extent of the tail, the minima of tail thickness, and velocity dispersions are in a very good agreement with the nbody6 simulations. This implies that the semi-analytic model can be used for estimating the properties of the gas expulsion tidal tail for a cluster of a given age and orbital parameters without the necessity of performing numerical simulations. A study with a more extended parameter space of the initial conditions is performed in the follow up paper.

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The JCMT BISTRO Survey: Magnetic fields associated with a network of filaments in NGC 1333

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We present new observations of the active star-formation region NGC 1333 in the Perseus molecular cloud complex from the James Clerk Maxwell Telescope (JCMT) B-Fields In Star-forming Region Observations (BISTRO) survey with the POL-2 instrument. The BISTRO data cover the entire NGC 1333 complex ($\sim$1.5 pc $\times$ 2 pc) at 0.02 pc

resolution and spatially resolve the polarized emission from individual filamentary structures for the first time. The inferred magnetic field structure is complex as a whole, with each individual filament aligned at different position angles relative to the local field orientation. We combine the BISTRO data with low- and high- resolution data derived from Planck and interferometers to study the multi-scale magnetic field structure in this region. The magnetic field morphology drastically changes below a scale of ∼1 pc and remains continuous from the scales of filaments (∼0.1 pc) to that of protostellar envelopes (∼0.005 pc or ∼1000 au). Finally, we construct simple models in which we assume that the magnetic field is always perpendicular to the long axis of the filaments. We demonstrate that the observed variation of the relative orientation between the filament axes and the magnetic field angles are well reproduced by this model, taking into account the projection effects of the magnetic field and filaments relative to the plane of the sky. These projection effects may explain the apparent complexity of the magnetic field structure observed at the resolution of BISTRO data towards the filament network.

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Multifrequency study of HH 137 and 138: Discovering new knots and molecular outflows with Gemini and APEX

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We present a multi-wavelength study of two HH objects (137 and 138) that may be associated. We use Gemini H_2 (2.12 μm) and K (2.2 μm) images, as well as APEX molecular line observations and Spitzer image archives. Several H_2 knots, linked to the optical chain of knots of HH 137, are identified in the Gemini and Spitzer 4.5 μm images. New shock excited regions related to the optical knots delineating HH 138 are also reported. In addition, a bright 4.5 μm 0.09 pc-long arc-shaped structure, roughly located mid-way between HH 137 and HH 138, is found to be associated with two Spitzer Class I/II objects, which are likely to be the exciting stars. These sources are almost coincident with a high-density molecular clump detected in ^{12}CO(3-2), ^{13}CO(3-2), C^{18}O(3-2), HCO$^+$(3-2) and HCN(3-2) molecular lines with an LTE mass of 36 $M_\odot$. The ^{12}CO(3-2) emission distribution over the observed region reveals molecular material underlying three molecular outflows. Two of them (outflows 1 and 2) are linked to all optical knots of HH 137 and HH 138 and to the H_2 and 4.5 μm shock emission knots. In fact, the outflow 2 shows an elongated ^{12}CO blue lobe that coincides with all the H_2 knots of HH 137 which end at a terminal H_2 bow shock. We propose a simple scenario that connects the outflows to the dust clumps detected in the region. A third possible outflow is located to the north-east projected towards a secondary weak and cold dust clump.

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Is T Tauri North a 'Classical' T Tauri star?

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We present high-resolution *H*- and *K*-band spectroscopic observations of the archetypal T Tauri star T Tau North. Synthetic spectral modeling is used to derive the *K*-band temperature, surface gravity, magnetic field strength, and rotational velocity for this star. The *K*-band spectroscopic temperature measured is $T_{K-band} = 3976 \pm 90$K, which is ~ 1000 K cooler than the temperature measured from optical observations. Our *K*-band temperature measurement for T Tau N is confirmed using equivalent width line ratio vs. temperature relations in the *H*-band, from which a $T_{H-band} = 4085 \pm 155$K is derived. This optical vs. IR temperature difference is interpreted as cool or hot spots, or

both, covering a significant part of the surface of T Tau N. The gravity derived for T Tau N $\log g = 3.45 \pm 0.14$ is lower than the gravity of nearly every other star in a sample of 24 classical T Tauri stars in Taurus. Combining these temperature and gravity results with magnetic stellar evolutionary models, we find the age of T Tau N to be less than 1 Myr old. These results suggest that T Tau N is in an earlier evolutionary stage than most classical T Tauri stars in Taurus, arguing that it is a protostar ejected from the embedded southern binary system shortly after its formation.

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ISO-ChaI 52: a weakly-accreting young stellar object with a dipper light curve

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We report on the discovery of periodic dips in the multiband lightcurve of ISO-ChaI 52, a young stellar object in the Chamaeleon I dark cloud. This is one among the peculiar objects that display very low or negligible accretion both in their UV continuum and spectral lines, although they present a remarkable infrared excess emission characteristic of optically-thick circumstellar disks. We have analyzed a VLT/X-Shooter spectrum with the tool ROTFIT to determine the stellar parameters. The latter, along with photometry from our campaign with the REM telescope and from the literature, have allowed us to model the spectral energy distribution and to estimate the size and temperature of the inner and outer disk. From the rotational period of the star/disk system of 3.45 days we estimate a disk inclination of 36°. The depth of the dips in different bands has been used to gain information about the occulting material. A single extinction law is not able to fit the observed behavior, while a two-component model of a disk warp composed of a dense region with a gray extinction and an upper layer with an ISM-type extinction provides a better fit of the data.

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A low-velocity bipolar outflow from a deeply embedded object in Taurus revealed by the Atacama Compact Array

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The first hydrostatic core, the first quasi-hydrostatic object formed during the star formation process, is still the observational missing link between the prestellar and protostellar phases, mainly due to its short lifetime. Although we have not established a clear method to identify this rare object, recent theoretical studies predict that the first core has millimeter continuum emission and low-velocity outflow with a wide opening angle. An extensive continuum/outflow survey toward a large number of "starless" cores in nearby star-forming regions works as a pathfinder. We observed

32 prestellar cores in Taurus with an average density of $>10^5$ cm^{-3} in 1.3 mm continuum and molecular lines using the ALMA-ACA stand-alone mode. Among the targets, MC35-mm centered at one of the densest "starless" cores in Taurus has blueshifted/redshifted wings in the ^{12}CO (2–1) line, indicating that there is deeply embedded object driving molecular outflow. The observed velocities and sizes of the possible outflow lobes are 2–4 km s^{-1}, and $\sim 2 \times 10^3$ au, respectively, and the dynamical time is calculated to be $\sim 10^3$ yr. In addition to this, the core is one of the strongest N_2D^+ (3–2) emitter in our sample. All the observed signatures do not conflict with any of the theoretical predictions about the first hydrostatic core so far, and thus MC35-mm is unique as the only first-core candidate in the Taurus molecular cloud.

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Analysis of Methanol Maser Flares in G107.298+5.63 and S255-NIRS3

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A 3D maser model has been used to perform an inverse problem on the light curves from three high-amplitude maser flares, selected on the basis of contemporaneous infra-red observations. Plots derived from the model recover the size of the maser cloud, and two parameters linked to saturation, from three observational properties of the light curve. Recovered sizes are consistent with independent interferometric measurements. Maser objects transition between weak and moderate saturation during a flare.

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Global Hydromagnetic Simulations of Protoplanetary Disks with Stellar Irradiation and Simplified Thermochemistry

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Outflows driven by large-scale magnetic fields likely play an important role in the evolution and dispersal of protoplanetary disks and in setting the conditions for planet formation. We extend our 2D-axisymmetric nonideal MHD model of these outflows by incorporating radiative transfer and simplified thermochemistry, with the dual aims of exploring how heating influences wind launching and illustrating how such models can be tested through observations of diagnostic spectral lines. Our model disks launch magnetocentrifugal outflows primarily through magnetic tension forces, so the mass-loss rate increases only moderately when thermochemical effects are switched on. For typical field strengths, thermochemical and irradiation heating are more important than magnetic dissipation. We furthermore find that the entrained vertical magnetic flux diffuses out of the disk on secular timescales as a result of nonideal MHD. Through postprocessing line radiative transfer, we demonstrate that spectral line intensities and moment-1 maps of atomic oxygen, the HCN molecule, and other species show potentially observable differences between a model with a magnetically driven outflow and one with a weaker, photoevaporative outflow. In particular, the line shapes and velocity asymmetries in the moment-1 maps could enable the identification of outflows emanating from the disk surface.

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The relative orientation between the magnetic field and gradients of surface brightness within thin velocity slices of ^{12}CO and ^{13}CO emission from the Taurus molecular cloud

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We examine the role of the interstellar magnetic field to modulate the orientation of turbulent flows within the Taurus molecular cloud using spatial gradients of thin velocity slices of ^{12}CO and ^{13}CO antenna temperatures. Our analysis accounts for the random errors of the gradients that arise from the thermal noise of the spectra. The orientations of the vectors normal to the antenna temperature gradient vectors are compared to the magnetic field orientations that are calculated from Planck 353 GHz polarization data. These relative orientations are parameterized with the projected Rayleigh statistic and mean resultant vector. For ^{12}CO, 28% and 39% of the cloud area exhibit strongly parallel or strongly perpendicular relative orientations respectively. For the lower opacity ^{13}CO emission, strongly parallel and strongly perpendicular orientations are found in 7% and 43% of the cloud area respectively. For both isotopologues, strongly parallel or perpendicular alignments are restricted to localized regions with low levels of turbulence. If the relative orientations serve as an observational proxy to the Alfvénic Mach number then our results imply local variations of the Alfvénic Mach number throughout the cloud.

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The Effect of Misalignment between Rotation Axis and Magnetic Field on Circumstellar Disk

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The formation of circumstellar disks is investigated using three-dimensional resistive magnetohydrodynamic simulations, in which the initial prestellar cloud has a misaligned rotation axis with respect to the magnetic field. We examine the effects of (i) the initial angle difference between the global magnetic field and the cloud rotation axis (θ_0) and (ii) the ratio of the thermal to gravitational energy (α_0). We study 16 models in total and calculate the cloud evolution until ~ 5000 yr after protostar formation. Our simulation results indicate that an initial non-zero θ_0 (> 0) promotes the disk formation but tends to suppress the outflow driving, for models that are moderately gravitationally unstable, $\alpha_0 \lesssim 1$. In these models, a large-sized rotationally-supported disk forms and a weak outflow appears, in contrast to a smaller disk and strong outflow in the aligned case ($\theta_0 = 0$). Furthermore, we find that when the initial cloud is highly unstable with small α_0, the initial angle difference θ_0 does not significantly affect the disk formation and outflow driving.

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Determining the Physical Conditions of an Extremely Young Class 0 Circumbinary Disk around VLA 1623A

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We present a detailed analysis of high-resolution C18O (2-1), SO (88-77), CO (3-2), and DCO+ (3-2) data obtained by the Atacama Large Millimeter/submillimeter Array toward a class 0 Keplerian circumbinary disk around VLA 1623A, which represents one of the most complete analyses toward a class 0 source. From the dendrogram analysis, we identified several accretion flows feeding the circumbinary disk in a highly anisotropic manner. Stream-like SO emission around the circumbinary disk reveals the complicated shocks caused by the interactions between the disk, accretion flows, and outflows. A wall-like structure is discovered south of VLA1623B. The discovery of two outflow cavity walls at the same position traveling at different velocities suggests that the two outflows from both VLA 1623A and VLA 1623B are on top of each other in the plane of the sky. Our detailed flat and flared disk modeling shows that Cycle 2 C18O J = 2-1 data are inconsistent with the combined binary mass of 0.2 Msun, as suggested by early Cycle 0 studies. The combined binary mass for VLA 1623A should be modified to 0.3-0.5 Msun.

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ALMA Survey of Orion Planck Galactic Cold Clumps (ALMASOP): I. Detection of New Hot Corinos with ACA

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We report the detection of four new hot corino sources, G211.47−19.27S, G208.68−19.20N1, G210.49−19.79W and G192.12−11.10 from a survey study of Planck Galactic Cold Clumps in the Orion Molecular Cloud Complex with the Atacama Compact Array (ACA). Three sources had been identified as low mass Class 0 protostars in the Herschel Orion Protostar Survey (HOPS). One source in the lambda Orionis region is firstly reported as a protostellar core. We have observed abundant complex organic molecules (COMs), primarily methanol but also other oxygen-bearing COMs (in G211.47−19.27S and G208.68−19.20N1) and the molecule of prebiotic interest NH_2CHO (in G211.47−19.27S), signifying the presence of hot corinos. While our spatial resolution is not sufficient for resolving most of the molecular emission structure, the large linewidth and high rotational temperature of COMs suggest that they likely reside in the hotter and innermost region immediately surrounding the protostar. In G211.47−19.27S, the D/H ratio of methanol ($[CH_2DOH]/[CH_3OH]$) and the $^{12}C/^{13}C$ ratio of methanol ($[CH_3OH]/[^{13}CH_3OH]$) are comparable to those of other hot corinos. Hydrocarbons and long carbon-chain molecules such as c-C_3H_2 and HCCCN are also detected in the four sources, likely tracing the outer and cooler molecular envelopes.

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$BV(RI)_c$ photometric study of three variable PMS stars in the field of V733 Cephei

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This paper report results from the first long-term $BV(RI)_c$ photometric CCD observations of three variable pre-main-sequence stars collected during the period from February 2007 to January 2020. The investigated stars are located in the field of the PMS star V733 Cep within the Cepheus OB3 association. All stars from our study show rapid photometric variability in all-optical passbands. In this paper, we describe and discuss the photometric behavior of these stars and the possible reasons for their variability. In the light variation of two of the stars we found periodicity.

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The ionized warped disk and disk wind of the massive protostar Monoceros R2-IRS2 seen with ALMA

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Theories of massive star formation predict that massive protostars accrete gas through circumstellar disks. Although several cases have been found already thanks to high-angular resolution interferometry, it remains unknown the internal physical structure of these disks and, in particular, whether they present warps or internal holes as observed in low-mass proto-planetary disks. Here, we report very high angular resolution observations of the H21α radio recombination line carried out in Band 9 with the Atacama Large Millimeter/submillimeter Array (beam of 80 mas$\times$60 mas, or 70 au$\times$50 au) toward the IRS2 massive young stellar object in the Monoceros R2 star-forming cluster. The H21α line shows maser amplification, which allows us to study the kinematics and physical structure of the ionised gas around the massive protostar down to spatial scales of $\sim$1-2 au. Our ALMA images and 3D radiative transfer modelling reveal that the ionized gas around IRS2 is distributed in a Keplerian circumstellar disk and an expanding wind. The H21α emission centroids at velocities between -10 and $20\,\mathrm{km\,s^{-1}}$ deviate from the disk plane, suggesting a warping for the disk. This could be explained by the presence of a secondary object (a stellar companion or a massive planet) within the system. The ionized wind seems to be launched from the disk surface at distances $\sim$11 au from the central star, consistent with magnetically-regulated disk wind models. This suggests a similar wind launching mechanism to that recently found for evolved massive stars such as MWC349A and MWC922.

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Spin-orbit alignment of the β Pictoris planetary system

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A crucial diagnostic that can tell us about processes involved in the formation and dynamical evolution of planetary systems is the angle between the rotation axis of a star and a planet's orbital angular momentum vector ("spin-orbit" alignment or "obliquity"). Here we present the first spin-orbit alignment measurement for a wide-separation exoplanetary system, namely on the directly imaged planet β Pictoris b. We use VLTI/GRAVITY spectro-interferometry with an astrometric accuracy of 1 μas (microarcsecond) in the Brγ photospheric absorption line to measure the photocenter displacement associated with the stellar rotation. Taking inclination constraints from astroseismology into account, we constrain the three-dimensional orientation of the stellar spin axis and find that β Pic b orbits its host star on a prograde orbit. The angular momentum vectors of the stellar photosphere, the planet, and the outer debris disk are well aligned with mutual inclinations $3^\circ \pm 5^\circ$, which indicates that β Pic b formed in a system without significant primordial misalignments. Our results demonstrate the potential of infrared interferometry to measure the spin-orbit

alignment for wide-separation planetary systems, probing a highly complementary regime to the parameter space accessible with the Rossiter-McLaughlin effect. If the low obliquity is confirmed by measurements on a larger sample of wide-separation planets, it would lend support to theories that explain the obliquity in Hot Jupiter systems with dynamical scattering and the Kozai-Lidov mechanism.

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Ionization: a possible explanation for the difference of mean disk sizes in star-forming regions

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Surveys of protoplanetary disks in star-forming regions of similar age revealed significant variations in average disk mass in some regions. For instance, disks in the Orion Nebular Cluster (ONC) and Corona Australis (CrA) are on average smaller than disks observed in Lupus, Taurus, Chamaeleon I, or Ophiuchus. In contrast to previous models that studied the truncation of disks at a late stage of their evolution, we investigate whether disks may already be born with systematically smaller disk sizes in more massive star-forming regions as a consequence of higher ionization rates. Assuming various cosmic-ray ionization rates, we computed the resistivities for ambipolar diffusion and Ohmic dissipation with a chemical network, and performed 2D nonideal magnetohydrodynamical protostellar collapse simulations. A higher ionization rate leads to stronger magnetic braking, and hence to the formation of smaller disks. Accounting for recent findings that protostars act as forges of cosmic rays and considering only mild attenuation during the collapse phase, we show that a high average cosmic-ray ionization rate in star-forming regions such as the ONC or CrA can explain the detection of smaller disks in these regions. Our results show that on average, a higher ionization rate leads to the formation of smaller disks. Smaller disks in regions of similar age can therefore be the consequence of different levels of ionization, and may not exclusively be caused by disk truncation through external photoevaporation. We strongly encourage observations that allow measuring the cosmic-ray ionization degrees in different star-forming regions to test our hypothesis.

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Linear dust polarization during the embedded phase of protostar formation: Synthetic observations of bridge structures

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Measuring polarization from thermal dust emission can provide important constraints on the magnetic field structure around embedded protostars. However, interpreting the observations is challenging without models that consistently account for both the complexity of the turbulent protostellar birth environment and polarization mechanisms. We aim to provide a better understanding of dust polarization maps of embedded protostars with a focus on bridge-like structures such as the structure observed toward the protostellar multiple system IRAS 16293–2422 by comparing synthetic polarization maps of thermal reemission with recent observations. We analyzed the magnetic field morphology and properties associated with the formation of a protostellar multiple based on ideal magnetohydrodynamic 3D zoom-in simulations carried out with the RAMSES code. To compare the models with observations, we postprocessed a snapshot of a bridge-like structure that is associated with a forming triple star system with the radiative transfer code POLARIS and produced multiwavelength dust polarization maps. The typical density in the most prominent bridge

of our sample is about $10^{-16}\,\mathrm{g\,cm^{-3}}$, and the magnetic field strength in the bridge is about 1 to 2 mG. Inside the bridge, the magnetic field structure has an elongated toroidal morphology, and the dust polarization maps trace the complex morphology. In contrast, the magnetic field strength associated with the launching of asymmetric bipolar outflows is significantly more magnetized (∼100 mG). At $\lambda = 1.3$ mm, and the orientation of the grains in the bridge is very similar for the case accounting for radiative alignment torques (RATs) compared to perfect alignment with magnetic field lines. However, the polarization fraction in the bridge is three times smaller for the RAT scenario than when perfect alignment is assumed. At shorter wavelength ($\lambda < 200\mu$m), however, dust polarization does not trace the magnetic field because other effects such as self-scattering and dichroic extinction dominate the orientation of the polarization. Compared to the launching region of protostellar outflows, the magnetic field in bridge-like structures is weak. Synthetic dust polarization maps of ALMA Bands 6 and 7 (1.3 mm and 870 μm, respectively) can be used as a tracer of the complex morphology of elongated toroidal magnetic fields associated with bridges.

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The Formation of a Stellar Association in the NGC 7000/IC 5070 Complex: Results from Kinematic Analysis of Stars and Gas

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We examine the clustering and kinematics of young stellar objects (YSOs) in the North America/Pelican Nebulae, as revealed by *Gaia* astrometry, in relation to the structure and motions of the molecular gas, as indicated in molecular line maps. The *Gaia* parallaxes and proper motions allow us to significantly refine previously published lists of YSOs, demonstrating that many of the objects previously thought to form a distributed population turn out to be non-members. The members are subdivided into at least 6 spatio-kinematic groups, each of which is associated with its own molecular cloud component or components. Three of the groups are expanding, with velocity gradients of 0.3–0.5 km s^{-1} pc^{-1}, up to maximum velocities of ∼8 km s^{-1} away from the groups' centers. The two known O-type stars associated with the region, 2MASS J20555125+4352246 and HD 199579, are rapidly escaping one of these groups, following the same position–velocity relation as the low-mass stars. We calculate that a combination of gas expulsion and tidal forces from the clumpy distribution of molecular gas could impart the observed velocity gradients within the groups. However, on a global scale, the relative motions of the groups do not appear either divergent or convergent. The velocity dispersion of the whole system is consistent with the kinetic energy gained due to gravitational collapse of the complex. Most of the stellar population has ages similar to the free-fall timescales for the natal clouds. Thus, we suggest the nearly free-fall collapse of a turbulent molecular cloud as the most likely scenario for star formation in this complex.

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The Mass-Size Relation and the Constancy of GMC Surface Densities in the Milky Way

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We use two existing molecular cloud catalogs derived from the same CO survey and two catalogs derived from local dust extinction surveys to investigate the nature of the GMC mass-size relation in the Galaxy. We find that the four surveys are well described by $M_{GMC} \sim R^2$ implying a constant mean surface density, Σ_{GMC}, for the cataloged clouds. However, the scaling coefficients and scatter differ significantly between the CO and extinction derived relations. We find that the additional scatter seen in the CO relations is due to a systematic variation in Σ_{GMC} with Galactic radius that is unobservable in the local extinction data. We decompose this radial variation of Σ_{GMC} into two components, a linear negative gradient with Galactic radius and a broad peak coincident with the molecular ring and superposed on the linear gradient. We show that the former may be due to a radial dependence of X_{CO} on metallicity while the latter likely results from a combination of increased surface densities of individual GMCs and a systematic upward bias in the measurements of Σ_{GMC} due to cloud blending in the molecular ring. We attribute the difference in scaling coefficients between the CO and extinction data to an underestimate of X_{CO}. We recalibrate the CO observations of nearby GMCs using extinction measurements to find that locally $X_{CO} = 3.6 \pm 0.3 \times 10^{20}$ cm^{-2} (K-km/s)$^{-1}$. We conclude that outside the molecular ring the GMC population of the Galaxy can be described to relatively good precision by a constant Σ_{GMC} of 35 M$_\odot$ pc^{-2}.

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The Future of IMF studies with the ELT and MICADO: The local Universe as a resolved IMF laboratory

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In this work, we aim to estimate the lowest stellar mass that MICADO at the ELT will be able to reliably detect given a stellar density and distance. We also show that instrumental effects that will play a critical role, and report the number of young clusters that will be accessible for IMF studies in the local Universe with the ELT. We used SimCADO, the instrument simulator package for the MICADO camera, to generate observations of 56 dense stellar regions with densities similar to the cores of young stellar clusters. We placed the cluster fields at distances between 8 kpc and 5 Mpc from the Earth, implying core densities from 10^2 to 10^5 stars arcsec^{-2}, and determined the lowest reliably observable mass for each stellar field through point-spread function (PSF) fitting photometry. Our results show that stellar densities of $< 10^3$ stars arcsec^{-2} will be easily resolvable by MICADO. The lowest reliably observable mass in the Large Magellanic Cloud will be around 0.1 M$_\odot$ for clusters with densities $< 10^3$ stars arcsec^{-2}. MICADO will be able to access the stellar content of the cores of all dense young stellar clusters in the Magellanic Clouds, allowing the peak and shape of the IMF to be studied in great detail outside the Milky Way. At a distance of 2 Mpc, all stars with $M > 2$ M$_\odot$ will be resolved in fields of $< 10^4$ stars arcsec^{-2}, allowing the high-mass end of the IMF to be studied in all galaxies out to and including NGC300. We show that MICADO on the ELT will be able to probe the IMF of star clusters that are ten times denser than what the James Webb Space Telescope will be able to access and over one hundred times denser than the clusters that the Hubble Space Telescope can successfully resolve. While the sensitivity of MICADO will not allow us to study the brown dwarf regime outside the Milky Way, it will enable access to all stellar members of over 1000 young clusters in the Milky Way and the Magellanic Clouds. Furthermore, direct measurements of the Salpeter slope of the IMF will be possible in over 1500 young clusters out to a distance of 5 Mpc. MICADO on the ELT will be able to measure resolved IMFs for a large ensemble of young clusters under starkly different environments and test the universality of the IMF in the local Universe.

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The origin of a distributed stellar population in the star-forming region W4

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Stellar kinematics provides the key to understanding the formation process and dynamical evolution of stellar systems. Here, we present a kinematic study of the massive star-forming region W4 in the Cassiopeia OB6 association using the Gaia Data Release 2 and high-resolution optical spectra. This star-forming region is composed of a core cluster

(IC 1805) and a stellar population distributed over 20 pc, which is a typical structural feature found in many OB associations. According to a classical model, this structural feature can be understood in the context of the dynamical evolution of a star cluster. The core-extended structure exhibits internally different kinematic properties. Stars in the core have an almost isotropic motion, and they appear to reach virial equilibrium given their velocity dispersion (0.9 ± 0.3 km s^{-1}) comparable to that in a virial state ($\sim$0.8 km s^{-1}). On the other hand, the distributed population shows a clear pattern of radial expansion. From the N-body simulation for the dynamical evolution of a model cluster in subvirial state, we reproduce the observed structure and kinematics of stars. This model cluster experiences collapse for the first 2 Myr. Some members begin to radially escape from the cluster after the initial collapse, eventually forming a distributed population. The internal structure and kinematics of the model cluster appear similar to those of W4. Our results support the idea that the stellar population distributed over 20 pc in W4 originate from the dynamical evolution of IC 1805.

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An unbiased ALMA spectral survey of the LkCa 15 and MWC 480 protoplanetary disks

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The volatile contents of protoplanetary disks both set the potential for planetary chemistry and provide valuable probes of defining disk system characteristics such as stellar mass, gas mass, ionization, and temperature structure. Current disk molecular inventories are fragmented, however, giving an incomplete picture: unbiased spectral line surveys are needed to assess the volatile content. We present here an overview of such a survey of the protoplanetary disks around the Herbig Ae star MWC 480 and the T Tauri star LkCa 15 in ALMA Band 7, spanning $\sim$36 GHz from 275–317 GHz and representing an order of magnitude increase in sensitivity over previous single-dish surveys. We detect 14 molecular species (including isotopologues), with 5 species ($C^{34}S$, ^{13}CS, H_2CS, DNC, and C_2D) detected for the first time in protoplanetary disks. Significant differences are observed in the molecular inventories of MWC 480 and LkCa 15, and we discuss how these results may be interpreted in light of the different physical conditions of these two disk systems.

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Dual-Wavelength ALMA Observations of Dust Rings in Protoplanetary Disks

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We present new Atacama Large Millimeter/submillimeter Array (ALMA) observations for three protoplanetary disks in Taurus at 2.9 mm and comparisons with previous 1.3 mm data both at an angular resolution of $\sim$0.″1 (15 au for the distance of Taurus). In the single-ring disk DS Tau, double-ring disk GO Tau, and multiple-ring disk DL Tau, the same rings are detected at both wavelengths, with radial locations spanning from 50 to 120 au. To quantify the dust emission morphology, the observed visibilities are modeled with a parametric prescription for the radial intensity profile. The disk outer radii, taken as 95% of the total flux encircled in the model intensity profiles, are consistent at both wavelengths for the three disks. Dust evolution models show that dust trapping in local pressure maxima in the outer disk could explain the observed patterns. Dust rings are mostly unresolved. The marginally resolved ring in DS Tau shows a tentatively narrower ring at the longer wavelength, an observational feature expected from efficient dust trapping. The spectral index ($\alpha_{\rm mm}$) increases outward and exhibits local minima that correspond to the peaks of dust rings, indicative of the changes in grain properties across the disks. The low optical depths ($\tau \sim$ 0.1–0.2 at 2.9 mm and 0.2–0.4 at 1.3 mm) in the dust rings suggest that grains in the rings may have grown to millimeter sizes. The ubiquitous dust rings in protoplanetary disks modify the overall dynamics and evolution of dust grains, likely paving the way towards the new generation of planet formation.

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Ongoing flyby in the young multiple system UX Tauri

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We present observations of the young multiple system UX Tauri to look for circumstellar disks and for signs of dynamical interactions. We obtained SPHERE/IRDIS deep differential polarization images in the J and H bands. We also used ALMA archival CO data. Large extended spirals are well detected in scattered light coming out of the disk of UX Tau A. The southern spiral forms a bridge between UX Tau A and C. These spirals, including the bridge connecting the two stars, all have a CO (3–2) counterpart seen by ALMA. The disk of UX Tau C is detected in scattered light. It is much smaller than the disk of UX Tau A and has a major axis along a different position angle, suggesting a misalignment. We performed PHANTOM SPH hydrodynamical models to interpret the data. The scattered light spirals, CO emission spirals and velocity patterns of the rotating disks, and the compactness of the disk of UX Tau C all point to a scenario in which UX Tau A has been perturbed very recently (about 1000 years) by the close passage of UX Tau C.

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Substructure Formation in a Protostellar Disk of L1527 IRS

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We analyze multi-frequency, high-resolution continuum data obtained by ALMA and JVLA to study detailed structure of the dust distribution in the infant disk of a Class 0/I source, L1527 IRS. We find three clumps aligning in the north-south direction in the 7 mm radio continuum image. The three clumps remain even after subtracting free-free contamination, which is estimated from the 1.3 cm continuum observations. The northern and southern clumps are located at a distance of ∼15 au from the central clump and are likely optically thick at 7 mm wavelength. The clumps have similar integrated intensities. The symmetric physical properties could be realized when a dust ring or spiral arms around the central protostar is projected to the plane of the sky. We demonstrates for the first time that such substructure may form even in the disk-forming stage, where the surrounding materials actively accrete toward a disk-protostar system.

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A planet within the debris disk around the pre-main-sequence star AU Microscopii

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AU Microscopii (AU Mic) is the second closest pre main sequence star, at a distance of 9.79 parsecs and with an age of 22 million years. AU Mic possesses a relatively rare and spatially resolved edge-on debris disk extending from about 35 to 210 astronomical units from the star, and with clumps exhibiting non-Keplerian motion. Detection of newly formed planets around such a star is challenged by the presence of spots, plage, flares and other manifestations of magnetic activity on the star. Here we report observations of a planet transiting AU Mic. The transiting planet, AU Mic b, has an orbital period of 8.46 days, an orbital distance of 0.07 astronomical units, a radius of 0.4 Jupiter radii, and a mass of less than 0.18 Jupiter masses at 3σ confidence. Our observations of a planet co-existing with a debris disk offer the opportunity to test the predictions of current models of planet formation and evolution.

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Variability of the Great Disk Shadow in Serpens

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We present multi-epoch Hubble Space Telescope imaging of the Great Disk Shadow in the Serpens star-forming region. The near-infrared images show strong variability of the disk shadow, revealing dynamics of the inner disk on time scales of months. The Great Shadow is projected onto the Serpens reflection nebula by an unresolved protoplanetary disk surrounding the young intermediate-mass star SVS2/CK3/EC82. Since the shadow extends out to a distance of at least 17,000 au, corresponding to a light travel time of 0.24 years, the images may reveal detailed changes in the disk scale height and position angle on time scales as short as a day, corresponding to the angular resolution of the images, and up to the 1.11 year span between two observing epochs. We present a basic retrieval of temporal changes in the disk density structure, based on the images. We find that the inner disk changes position angle on time scales of months, and that the change is not axisymmetric, suggesting the presence of a non-axisymmetric dynamical forcing on $\sim$1 au size scales. We consider two different scenarios, one in which a quadrupolar disk warp orbits the central star, and one in which an unequal-mass binary orbiting out of the disk plane displaces the photo-center relative to the shadowing disk. Continued space-based monitoring of the Serpens Disk Shadow is required to distinguish between these scenarios, and could provide unique, and detailed, insight into the dynamics of inner protoplanetary disks not available through other means.

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The circumstellar environment of EX Lup: SPHERE and SINFONI views

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EX Lup is a well-studied T Tauri star that represents the prototype of young eruptive stars known as EXors. They are characterized by repetitive outbursts that are due to enhanced accretion from the circumstellar disk onto the star. In this paper, we analyze new adaptive optics imaging and spectroscopic observations to study EX Lup and its circumstellar environment in near-infrared in its quiescent phase. We aim to provide a comprehensive understanding of the circumstellar environment around EX Lup in quiescence, building upon the vast store of data provided by the literature. We observed EX Lup in quiescence with the high contrast imager SPHERE/IRDIS in the dual-beam polarimetric imaging mode to resolve the circumstellar environment in near-infrared scattered light. We complemented the data with earlier SINFONI spectroscopy, which was also taken in quiescence. We resolve, for the first time in scattered light, a compact feature around EX Lup azimuthally extending from $\sim 280°$ to $\sim 360°$ and radially extending from $\sim 0.3''$ to $\sim 0.55''$ in the plane of the disk. We explore two different scenarios for the detected emission. The first one accounts for the emission as coming from the brightened walls of the cavity excavated by the outflow whose presence was suggested by ALMA observations in the $J = 3-2$ line of ^{12}CO. The second attributes the emission to an inclined disk. In this latter case, we detect, for the first time, a more extended circumstellar disk in scattered light, which shows that a region between $\sim$10 and $\sim$30 au is depleted of μm-size grains. We compare the J−, H−, and K−band spectra obtained with SINFONI in quiescence with the spectra taken during the outburst, showing that all the emission lines result from the episodic accretion event. Based on the morphology analysis, we favor the scenario that assumes the scattered light is coming from a circumstellar disk rather than the outflow around EX Lup. We determine the origin of the observed feature as either coming from a continuous circumstellar disk with a cavity, from the illuminated wall of the outer disk, or from a shadowed disk. Moreover, we discuss the potential origins of the depleted region of μm-size grains, exploring the possibility that a sub-stellar companion may be the source of this feature.

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Ring formation and dust dynamics in wind-driven protoplanetary discs: global simulations

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Large-scale vertical magnetic fields are believed to play a key role in the evolution of protoplanetary discs. Associated with non-ideal effects, such as ambipolar diffusion, they are known to launch a wind that could drive accretion in the outer part of the disc ($R > 1$ AU). They also potentially lead to self-organisation of the disc into large-scale axisymmetric structures, similar to the rings recently imaged by sub-millimetre or near-infrared instruments (ALMA and SPHERE). The aim of this paper is to investigate the mechanism behind the formation of these gaseous rings, but also to understand the dust dynamics and its emission in discs threaded by a large-scale magnetic field. To this end, we performed global magneto-hydrodynamics (MHD) axisymmetric simulations with ambipolar diffusion using a modified version of the PLUTO code. We explored different magnetisations with the midplane β parameter ranging from 10^5 to 10^3 and included dust grains – treated in the fluid approximation – ranging from 100 μm to 1 cm in size. We first show that the gaseous rings (associated with zonal flows) are tightly linked to the existence of MHD winds. Secondly, we find that millimetre-size dust is highly sedimented, with a typical scale height of 1 AU at $R = 100$ AU for $\beta = 10^4$, compatible with recent ALMA observations. We also show that these grains concentrate

into pressure maxima associated with zonal flows, leading to the formation of dusty rings. Using the radiative transfer code MCFOST, we computed the dust emission and make predictions on the ring-gap contrast and the spectral index that one might observe with interferometers like ALMA.

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Characterizing the radio continuum nature of sources in the massive star-forming region W75N (B)

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The massive star-forming region W75N (B) is thought to host a cluster of massive protostars (VLA 1, VLA 2, and VLA 3) undergoing different evolutionary stages. In this work, we present radio continuum data with the highest sensitivity and angular resolution obtained to date in this region, using the VLA-A and covering a wide range of frequencies (4-48 GHz), which allowed us to study the morphology and the nature of the emission of the different radio continuum sources. We also performed complementary studies with multi-epoch VLA data and ALMA archive data at 1.3 mm wavelength. We find that VLA 1 is driving a thermal radio jet at scales of ≈0.1 arcsec (≈130 au), but also shows signs of an incipient hyper-compact HII region at scales of $\lesssim$ 1 arcsec ($\lesssim$ 1300 au). VLA 3 is also driving a thermal radio jet at scales of a few tenths of arcsec (few hundred of au). We conclude that this jet is shock-exciting the radio continuum sources Bc and VLA 4 (obscured HH objects), which show proper motions moving outward from VLA 3 at velocities of ≈112–118 km/s. We have also detected three new weak radio continuum sources, two of them associated with millimeter continuum cores observed with ALMA, suggesting that these two sources are also embedded YSOs in this massive star-forming region.

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The Role of Outflows, Radiation Pressure, and Magnetic Fields in Massive Star Formation

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Stellar feedback in the form of radiation pressure and magnetically-driven collimated outflows may limit the maximum mass that a star can achieve and affect the star-formation efficiency of massive pre-stellar cores. Here we present a series of 3D adaptive mesh refinement radiation-magnetohydrodynamic simulations of the collapse of initially turbulent,

massive pre-stellar cores. Our simulations include radiative feedback from both the direct stellar and dust-reprocessed radiation fields, and collimated outflow feedback from the accreting stars. We find that protostellar outflows punches holes in the dusty circumstellar gas along the star's polar directions, thereby increasing the size of optically thin regions through which radiation can escape. Precession of the outflows as the star's spin axis changes due to the turbulent accretion flow further broadens the outflow, and causes more material to be entrained. Additionally, the presence of magnetic fields in the entrained material leads to broader entrained outflows that escape the core. We compare the injected and entrained outflow properties and find that the entrained outflow mass is a factor of $\sim$3 larger than the injected mass and the momentum and energy contained in the entrained material are $\sim$25% and $\sim$5% of the injected momentum and energy, respectively. As a result, we find that, when one includes both outflows and radiation pressure, the former are a much more effective and important feedback mechanism, even for massive stars with significant radiative outputs.

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Planet Migration in Self-Gravitating Discs: Survival of Planets

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We carry out three-dimensional SPH simulations to study whether planets can survive in self-gravitating protoplanetary discs. The discs modelled here use a cooling prescription that mimics a real disc which is only gravitationally unstable in the outer regions. We do this by modelling the cooling using a simplified method such that the cooling time in the outer parts of the disc is shorter than in the inner regions, as expected in real discs. We find that both giant ($> M_{\rm Sat}$) and low mass ($< M_{\rm Nep}$) planets initially migrate inwards very rapidly, but are able to slow down in the inner gravitationally stable regions of the disc without needing to open up a gap. This is in contrast to previous studies where the cooling was modelled in a more simplified manner where regardless of mass, the planets were unable to slow down their inward migration. This shows the important effect the thermodynamics has on planet migration. In a broader context, these results show that planets that form in the early stages of the discs' evolution, when they are still quite massive and self-gravitating, can survive.

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A census of young stellar population associated with the Herbig Be star HD 200775

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The region surrounding the well-known reflection nebula, NGC 7023, illuminated by a Herbig Be star, HD 200775, located in the dark cloud L1174 is studied in this work. Based on the distances and proper motion values from *Gaia* DR2 of 20 previously known young stellar object (YSO) candidates, we obtained a distance of 335 $\pm$ 11 pc to the cloud complex L1172/1174. Using polarization measurements of the stars projected on the cloud complex, we show additional evidence for the cloud to be at $\sim$ 335 pc distance. Using this distance and proper motion values of the YSO candidates, we searched for additional comoving sources in the vicinity of HD 200775 and found 20 new sources, which show low infrared excess emission and are of age $\sim$ 1 Myr. Among these, 10 YSO candidates and 4 newly identified

comoving sources are found to show X-ray emission. Three of the four new sources for which we have obtained optical spectra show H α in emission. About 80 per cent of the total sources are found within $\sim$ 1 pc distance from HD 200775. Spatial correlation of some of the YSO candidates with the *Herschel* dust column density peaks suggests that star formation is still active in the region and may have been triggered by HD 200775.

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Twin Jets and Close Binary Formation

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The formation of a close binary system is investigated using a three-dimensional resistive magnetohydrodynamics simulation. Starting from a prestellar cloud, the cloud evolution is calculated until $\sim$ 400 yr after protostar formation. Fragmentation occurs in the gravitationally collapsing cloud and two fragments evolve into protostars. The protostars orbit each other and a protobinary system appears. A wide-angle low-velocity outflow emerges from the circumbinary streams that encloses two protostars, while each protostar episodically drives high-velocity jets. Thus, the two high-velocity jets are surrounded by the low-velocity circumbinary outflow. The speed of the jets exceeds $\gtrsim$100 km s^{-1}. Although the jets have a collimated structure, they are swung back on the small scale and are tangled at the large scale due to the binary orbital motion. A circumstellar disk also appears around each protostar. In the early main accretion phase, the binary orbit is complicated, while the binary separation is within $<$ 30 au. For the first time, all the characteristics of protobinary systems recently observed with large telescopes are reproduced in a numerical simulation.

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Bipolar molecular outflow of the very low-mass star Par-Lup3-4

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Very low-mass stars are known to have jets and outflows, which is indicative of a scaled-down version of low-mass star formation. However, only very few outflows in very low-mass sources are well characterized. We characterize the bipolar molecular outflow of the very low-mass star Par-Lup3-4, a 0.12 $M_\odot$ object known to power an optical jet. We observed Par-Lup3-4 with ALMA in Bands 6 and 7, detecting both the continuum and CO molecular gas. In particular, we studied three main emission lines: CO(2-1), CO(3-2), and ^{13}CO(3-2). Our observations reveal for the first time the base of a bipolar molecular outflow in a very low-mass star, as well as a stream of material moving perpendicular to the primary outflow of this source. The primary outflow morphology is consistent with the previously determined jet orientation and disk inclination. The outflow mass is $9.5\times10^{-7} M_\odot$, with an outflow rate of $4.3\times10^{-9} M_\odot$/yr. A new fitting to the spectral energy distribution suggests that Par-Lup3-4 may be a binary system. We have characterized Par-Lup3-4 in detail, and its properties are consistent with those reported in other very low-mass sources. This source provides further evidence that very low-mass sources form as a scaled-down version of low-mass stars.

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Orbital Motion, Variability, and Masses in the T Tauri Triple System

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We present results from adaptive optics imaging of the T Tauri triple system obtained at the Keck and Gemini Observatories in 2015−2019. We fit the orbital motion of T Tau Sb relative to Sa and model the astrometric motion of their center of mass relative to T Tau N. Using the distance measured by Gaia, we derived dynamical masses of $M_{\rm Sa} = 2.05 \pm 0.14$ M$_\odot$ and $M_{\rm Sb} = 0.43 \pm 0.06$ M$_\odot$. The precision in the masses is expected to improve with continued observations that map the motion through a complete orbital period; this is particularly important as the system approaches periastron passage in 2023. Based on published properties and recent evolutionary tracks, we estimate a mass of ~ 2 M$_\odot$ for T Tau N, suggesting that T Tau N is similar in mass to T Tau Sa. Narrow-band infrared photometry shows that T Tau N remained relatively constant between late 2017 and early 2019 with an average value of $K = 5.54 \pm 0.07$ mag. Using T Tau N to calibrate relative flux measurements since 2015, we found that T Tau Sa varied dramatically between 7.0 to 8.8 mag in the K-band over timescales of a few months, while T Tau Sb faded steadily from 8.5 to 11.1 mag in the K-band. Over the 27 year orbital period of the T Tau S binary, both components have shown 3–4 magnitudes of variability in the K-band, relative to T Tau N.

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Discovery of a jet from the single HAe/Be star HD 100546

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Young accreting stars drive outflows that collimate into jets, which can be seen hundreds of au from their driving sources. Accretion and outflow activity cease with system age, and it is believed that magneto-centrifugally launched disk winds are critical agents in regulating accretion through the protoplanetary disk. Protostellar jets are well studied in classical T Tauri stars ($M_\star \lesssim 2\,M_\odot$), while few nearby ($d \lesssim 150\,$pc) intermediate-mass stars ($M_\star = 2 - 10\,M_\odot$), known as Herbig Ae/Be stars, have detected jets. We report VLT/MUSE observations of the Herbig Ae/Be star HD 100546 and the discovery of a protostellar jet. The jet is similar in appearance to jets driven by low-mass stars and compares well with the jet of HD 163296, the only other known optical jet from a nearby Herbig Ae/Be star. We derive a (one-sided) mass-loss rate in the jet of $\log \dot{M}_{jet} \sim -9.5$ (in $M_\odot\,{\rm yr}^{-1}$) and a ratio of outflow to accretion of roughly 3×10^{-3}, which is lower than that of CTTS jets.
The discovery of the HD 100546 jet is particularly interesting because the protoplanetary disk around HD 100546 shows a large radial gap, spiral structure, and might host a protoplanetary system. A bar-like structure previously seen in Hα with VLT/SPHERE shares the jet position angle, likely represents the base of the jet, and suggests a jet-launching region within about 2 au. We conclude that the evolution of the disk at radii beyond a few au does not

affect the ability of the system to launch jets.

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Rapid Elimination of Small Dust Grains in Molecular Clouds

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We argue that impact velocities between dust grains with sizes less than ∼0.1 μm in molecular cloud cores are dominated by drift arising from ambipolar diffusion. This effect is due to the size dependence of the dust coupling to the magnetic field and the neutral gas. Assuming perfect sticking in collisions up to ≈50 $\mathrm{m\,s^{-1}}$, we show that this effect causes rapid depletion of small grains — consistent with starlight extinction and IR/microwave emission measurements, both in the core center ($n \sim 10^6$ cm^{-3}) and envelope ($n \sim 10^4$ cm^{-3}). The upper end of the size distribution does not change significantly if only velocities arising from this effect are considered. We consider the impact of an evolved dust size distribution on the gas temperature, and argue that if the depletion of small dust grains occurs as would be expected from our model, then the cosmic ray ionization rate must be well below 10^{-16} s^{-1} at a number density of 10^5 cm^{-3}.

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Seeds of Life in Space (SOLIS) VIII. SiO isotopic fractionation and a new insight in the shocks of L1157-B1

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L1157-B1 is one of the outflow shocked regions along the blue-shifted outflow driven by the Class 0 protostar L1157-mm, and is an ideal laboratory to study the material ejected from the grains in very short timescales, i.e. its chemical composition is representative of the composition of the grains. We imaged ^{28}SiO, ^{29}SiO and ^{30}SiO $J = 2$–1 emission towards L1157-B1 and B0 with the NOrthern Extended Millimeter Array (NOEMA) interferometer as part of the Seeds of Life in Space (SOLIS) large project. We present here a study of the isotopic fractionation of SiO towards L1157-B1. Furthermore, we use the high spectral resolution observations on the main isotopologue, ^{28}SiO, to study the jet impact on the dense gas. We present here also single-dish observations obtained with the IRAM 30m telescope and Herschel-HIFI. We carried out a non-LTE analysis using a Large Velocity Gradient (LVG) code to model the single-dish observations. From our observations we can show that (i) the (2–1) transition of the main isotopologue is optically thick in L1157-B1 even at high velocities, and (ii) the [^{29}SiO/^{30}SiO] ratio is constant across the source, and consistent with the solar value of 1.5. We report the first isotopic fractionation maps of SiO in a shocked region and show the absence of a mass dependent fractionation in ^{29}Si and ^{30}Si across L1157-B1. A high-velocity bullet in ^{28}SiO has been identified, showing the signature of a jet impacting on the dense gas. With the dataset presented in this paper, both interferometric and single-dish, we were able to study in great detail the gas shocked at the B1a position and its surrounding gas.

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Circumbinary Disks of the Protostellar Binary Systems in the L1551 Region

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We report ALMA Cycle 4 observations of the Class I binary protostellar system L1551 IRS 5 in the 0.9-mm continuum emission, $C^{18}O$ (J=3–2), OCS (J=28–27), and four other Band 7 lines. At $\sim 0\farcs07$ (= 10 au) resolution in the 0.9 mm emission, two circumstellar disks (CSDs) associated with the binary protostars are separated from the circumbinary disk (CBD). The CBD is resolved into two spiral arms, one connecting to the CSD around the northern binary source, Source N, and the other to Source S. As compared to the CBD in the neighboring protobinary system L1551 NE, the CBD in L1551 IRS 5 is more compact ($r \sim$150 au) and the m=1 mode of the spirals found in L1551 NE is less obvious in L1551 IRS 5. Furthermore, the dust and molecular-line brightness temperatures of CSDs and CBD reach >260 K and >100 K, respectively, in L1551 IRS 5, much hotter than those in L1551 NE. The gas motions in the spiral arms are characterized by rotation and expansion. Furthermore, the transitions from the CBD to the CSD rotations at around the L2 and L3 Lagrangian points and gas motions around the L1 point are identified. Our numerical simulations reproduce the observed two spiral arms and expanding gas motion as a result of gravitational torques from the binary, transitions from the CBD to the CSD rotations, and the gas motion around the L1 point. The higher temperature in L1551 IRS 5 likely reflects the inferred FU-Ori event.

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An infrared study of the high-mass, multi-stage star-forming region IRAS 12272-6240

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IRAS 12272-6240 is a complex star forming region with a compact massive dense clump and several associated masers, located at a well-determined distance of d = 9.3 kpc from the Sun. For this study, we obtained sub-arcsec broad- and narrow-band near-IR imaging and low-resolution spectroscopy with the Baade/Magellan telescope and its camera PANIC. Mosaics of size 2×2 square arcmin in the JHK_s bands and with narrow-band filters centred in the 2.12 μm H_2 and 2.17 μm Brγ lines were analysed in combination with HI-GAL/*Herschel* and archive IRAC/*Spitzer* and *WISE* observations. We found that the compact dense clump houses two Class I YSOs that probably form a 21 kAU-wide binary system. Its combined 1 to 1200 μm SED is consistent with an O9V central star with a $10^{-2} M_\odot$ disc and a $1.3 \times 10^4 M_\odot$ dust envelope. Its total luminosity is $8.5 \times 10^4 L_\odot$. A series of shocked H_2 emission knots are found in its close vicinity, confirming the presence of outflows. IRAS 12272-6240 is at the centre of an embedded cluster with a mean age of 1 Myr and 2.6 pc in size that contains more than 150 stars. At its nucleus, we found a more compact and considerably younger sub-cluster containing the YSOs. We also identified and classified the O-type central stars of two dusty radio/IR HII regions flanking the protostars. Our results confirm that these elements form a single giant young complex where massive star formation processes started some 1 million years ago and is still active.

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FRagmentation and Evolution of dense cores Judged by ALMA (FREJA). I (Overview). Inner ∼1,000 au structures of prestellar/protostellar cores in Taurus

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We have performed survey-type observations in 1 mm continuum and molecular lines toward dense cores (32 prestellar + 7 protostellar) with an average density of $>10^5\,\mathrm{cm^{-3}}$ in the Taurus molecular clouds using the ALMA-ACA (Atacama Compact Array) stand-alone mode with an angular resolution of 6.″5 (∼900 au). The primary purpose of this study is to investigate the innermost part of dense cores toward understanding the initial condition of star formation.

In the protostellar cores, contributions from protostellar disks dominate the observed continuum flux with a range of 35–90% except for the very low-luminosity object. For the prestellar cores, we have successfully confirmed continuum emission from dense gas with a density of $>3\times10^5\,\mathrm{cm^{-3}}$ toward approximately one-third of the targets. Thanks to the lower spatial frequency coverage with the ACA-7 m array, the detection rate is significantly higher than that of the previous surveys, which have 0 or 1 continuum detected sources among large number of starless samples using the ALMA Main array. The statistical counting method tells us that the lifetime of the prestellar cores until protostar formation therein approaches the free-fall time as the density increases. Among the prestellar cores, at least two targets have possible internal substructures, which are detected in continuum emission with the size scale of ∼1000 au if we consider the molecular line ($C^{18}O$ and N_2D^+) distributions. These results suggest that small scale fragmentation/coalescence processes within a <0.1 pc scale region occur to determine the final core mass leading to protostars before the dynamical collapse whose central density range is $\sim(0.3\text{–}1)\times10^6\,\mathrm{cm^{-3}}$.

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Early evolution of disk, outflow, and magnetic field of young stellar objects: Impact of dust model

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The formation and early evolution of low mass young stellar objects (YSOs) are investigated using three-dimensional non-ideal magneto-hydrodynamics simulations. We investigate the evolution of YSOs up to $\sim10^4$ yr after protostar formation, at which protostellar mass reaches ∼0.1 $M_\odot$. We particularly focus on the impact of the dust model on the evolution. We found that a circumstellar disk is formed in all simulations regardless of the dust model. Disk size is approximately 10 AU at the protostar formation epoch, and it increases to several tens of AU at $\sim10^4$ yr after protostar formation. Disk mass is comparable to central protostellar mass and gravitational instability develops. In the simulations with small dust size, the warp of the pseudodisk develops $\sim10^4$ yr after protostar formation. The warp strengthens magnetic braking in the disk and decreases disk size. Ion-neutral drift can occur in the infalling envelope under the conditions that the typical dust size is a $\gtrsim 0.2\ \mu$m and the protostar (plus disk) mass is $M \gtrsim 0.1\ M_\odot$. The

outflow activity is anti-correlated to the dust size and the strong outflow appears with small dust grains.

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Dust masses of young disks: constraining the initial solid reservoir for planet formation

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In recent years evidence has been building that planet formation starts early, in the first ~ 0.5 Myr. Studying the dust masses available in young disks enables understanding the origin of planetary systems since mature disks are lacking the solid material necessary to reproduce the observed exoplanetary systems, especially the massive ones. We aim to determine if disks in the embedded stage of star formation contain enough dust to explain the solid content of the most massive exoplanets. We use Atacama Large Millimeter/submillimeter Array (ALMA) Band 6 observations of embedded disks in the Perseus star-forming region together with Very Large Array (VLA) Ka-band (9 mm) data to provide a robust estimate of dust disk masses from the flux densities. Using the DIANA opacity model including large grains, with a dust opacity value of $\kappa_{9\ \rm mm} = 0.28$ cm^2 g^{-1}, the median dust masses of the embedded disks in Perseus are 158 $M_\oplus$ for Class 0 and 52 $M_\oplus$ for Class I from the VLA fluxes. The lower limits on the median masses from ALMA fluxes are 47 $M_\oplus$ and 12 $M_\oplus$ for Class 0 and Class I, respectively, obtained using the maximum dust opacity value $\kappa_{1.3\rm mm} = 2.3$ cm^2 g^{-1}. The dust masses of young Class 0 and I disks are larger by at least a factor of 10 and 3, respectively, compared with dust masses inferred for Class II disks in Lupus and other regions. The dust masses of Class 0 and I disks in Perseus derived from the VLA data are high enough to produce the observed exoplanet systems with efficiencies acceptable by planet formation models: the solid content in observed giant exoplanets can be explained if planet formation starts in Class 0 phase with an efficiency of $\sim 15\%$. Higher efficiency of $\sim 30\%$ is necessary if the planet formation is set to start in Class I disks.

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Accretion bursts in low-metallicity protostellar disks

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The early evolution of protostellar disks with metallicities in the $Z = 1.0$–$0.01\ Z_\odot$ range was studied with a particular emphasis on the strength of gravitational instability and the nature of protostellar accretion in low-metallicity systems. Numerical hydrodynamics simulations in the thin-disk limit were employed that feature separate gas and dust temperatures, and disk mass-loading from the infalling parental cloud cores. Models with cloud cores of similar initial mass and rotation pattern, but distinct metallicity were considered to distinguish the effect of metallicity from that of initial conditions. The early stages of disk evolution in low-metallicity models are characterized by vigorous gravitational instability and fragmentation. Disk instability is sustained by continual mass-loading from the collapsing core. The time period that is covered by this unstable stage is much shorter in the $Z = 0.01\ Z_\odot$ models as compared

to their higher metallicity counterparts thanks to the higher mass infall rates caused by higher gas temperatures (that decouple from lower dust temperatures) in the inner parts of collapsing cores. Protostellar accretion rates are highly variable in the low-metallicity models reflecting a highly dynamical nature of the corresponding protostellar disks. The low-metallicity systems feature short, but energetic episodes of mass accretion caused by infall of inward-migrating gaseous clumps that form via gravitational fragmentation of protostellar disks. These bursts seem to be more numerous and last longer in the $Z = 0.1\ Z_{\odot}$ models in comparison to the $Z = 0.01\ Z_{\odot}$ case. Variable protostellar accretion with episodic bursts is not a particular feature of solar metallicity disks. It is also inherent to gravitationally unstable disks with metallicities up to 100 times lower than solar.

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Promoted Mass Growth of Multiple, Distant Giant Planets through Pebble Accretion and Planet-Planet Collision

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We propose a pebble-driven planet formation scenario to form giant planets with high multiplicity and large orbital distances in the early gas disk phase. We perform N-body simulations to investigate the growth and migration of low-mass protoplanets in the disk with inner viscously heated and outer stellar irradiated regions. The key feature of this model is that the giant planet cores grow rapidly by a combination of pebble accretion and planet-planet collisions. This consequently speeds up their gas accretion. Because of efficient growth, the planet transitions from rapid type I migration to slow type II migration early, reducing the inward migration substantially. Multiple giant planets can sequentially form in this way with increasing semimajor axes. Both mass growth and orbital retention are more pronounced when a large number of protoplanets are taken into account compared to the case of single planet growth. Eventually, a few numbers of giant planets form with orbital distances of a few to a few tens of AUs within 1.5–3 Myr after the birth of the protoplanets. The resulting simulated planet populations could be linked to the substructures exhibited in disk observations as well as large orbital distance exoplanets observed in radial velocity and microlensing surveys.

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Testing viscous disc theory using the balance between stellar accretion and external photoevaporation of protoplanetary discs

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The nature and rate of (viscous) angular momentum transport in protoplanetary discs (PPDs) has important consequences for the formation process of planetary systems. While accretion rates onto the central star yield constraints on such transport in the inner regions of a PPD, empirical constraints on viscous spreading in the outer regions remain challenging to obtain. Here we demonstrate a novel method to probe the angular momentum transport at the outer edge of the disc. This method applies to PPDs that have lost a significant fraction of their mass due to thermal winds driven by UV irradiation from a neighbouring OB star. We demonstrate that this external photoevaporation can explain the observed depletion of discs in the 3–5 Myr old σ Orionis region, and use our model to make predictions motivating future empirical investigations of disc winds. For populations of intermediate-age PPDs, in viscous models we show that the mass flux outwards due to angular momentum redistribution is balanced by the mass-loss in the photoevaporative wind. A comparison between wind mass-loss and stellar accretion rates therefore offers an independent constraint on viscous models in the outer regions of PPDs.

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Rotation of Two Micron All Sky Survey Clumps in Molecular Clouds

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We have analyzed the rotational properties of 12 clumps using ^{13}CO (1–0) and C^{18}O (1–0) maps of the Five College Radio Astronomy Observatory 13.7 m radio telescope. The clumps, located within molecular clouds, have radii (R) in the range of $0.06 - 0.27$ pc. The direction of clump elongation is not correlated with the direction of the velocity gradient. We measured the specific angular momentum (J/M) to be between 0.0022 and 0.025 pc km s^{-1} based on ^{13}CO images, and between 0.0025 and 0.021 pc km s^{-1} based on C^{18}O images. The consistency of J/M based on different tracers indicates the ^{13}CO and C^{18}O in dense clumps trace essentially the same material despite significantly different opacities. We also found that J/M increases monotonically as a function of R in power–law form, $J/M \propto R^{1.58 \pm 0.11}$. The ratio between rotation energy and gravitational energy, β, ranges from 0.0012 to 0.018. The small values of β imply that rotation alone is not sufficient to support the clump against gravitational collapse.

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Super-resolution Imaging of the Protoplanetary Disk HD 142527 Using Sparse Modeling

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With an emphasis on improving the fidelity even in super-resolution regimes, new imaging techniques have been intensively developed over the last several years, which may provide substantial improvements to the interferometric observation of protoplanetary disks. In this study, sparse modeling (SpM) is applied for the first time to observational data sets taken by the Atacama Large Millimeter/submillimeter Array (ALMA). The two data sets used in this study were taken independently using different array configurations at Band 7 (330 GHz), targeting the protoplanetary disk around HD 142527; one in the shorter-baseline array configuration ($\sim$430 m), and the other in the longer-baseline array configuration ($\sim$1570 m). The image resolutions reconstructed from the two data sets are different by a factor of $\sim$3. We confirm that the previously known disk structures appear on the images produced by both SpM and CLEAN at the standard beam size. The image reconstructed from the shorter-baseline data using the SpM matches that obtained with the longer-baseline data using CLEAN, achieving a super-resolution image from which a structure finer than the beam size can be reproduced. Our results demonstrate that on-going intensive development in the SpM

imaging technique is beneficial to imaging with ALMA.

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Distances and statistics of local molecular clouds in the first Galactic quadrant

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We present an analysis of local molecular clouds ($-6 < V_{\rm LSR} < 30$ km s^{-1}, i.e., <1.5 kpc) in the first Galactic quadrant ($25\overset{\circ}{.}8 < l < 49\overset{\circ}{.}7$ and $|b| < 5°$), a pilot region of the Milky Way Imaging Scroll Painting (MWISP) CO survey. Using the SCIMES algorithm to divide large molecular clouds into moderate-sized ones, we determined distances to 28 molecular clouds with the background-eliminated extinction-parallax (BEEP) method using the Gaia DR2 parallax measurements aided by A_G and A_V, and the distance ranges from 250 pc to about 1.5 kpc. These incomplete distance samples indicate a linear relationship between the distance and the radial velocity ($V_{\rm LSR}$) with a scatter of 0.16 kpc, and kinematic distances may be systematically larger for local molecular clouds. In order to investigate fundamental properties of molecular clouds, such as the total sample number, the linewidth, the brightness temperature, the physical area, and the mass, we decompose the spectral cube using the DBSCAN algorithm. Post selection criteria are imposed on DBSCAN clusters to remove the noise contamination, and we found that the separation of molecular cloud individuals is reliable based on a definition of independent consecutive structures in l-b-V space. The completeness of the local molecular cloud flux collected by the MWISP CO survey is about 80%. The physical area, A, shows a power-law distribution, $dN/dA \propto A^{-2.20\pm0.18}$, while the molecular cloud mass also follows a power-law distribution but slightly flatter, $dN/dM \propto M^{-1.96\pm0.11}$.

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Resolution-dependent Subsonic Non-thermal Line Dispersion Revealed by ALMA

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We report here Atacama Large Millimeter/submillimeter Array (ALMA) N_2H^+ (1-0) images of the Orion Molecular Cloud 2 and 3 (OMC-2/3) with high angular resolution (3" or 1200 au) and high spatial dynamic range. Combining dataset from the ALMA main array, ALMA Compact Array (ACA), the Nobeyama 45m Telescope, and the JVLA (providing temperature measurement on matching scales), we find that most of the dense gas in OMC-2/3 is subsonic ($\sigma_{\rm NT}/c_{\rm s} = 0.62$) with a mean line width (Δv) of 0.39 km s^{-1} FWHM. This is markedly different from the majority of previous observations of massive star-forming regions. In contrast, line widths from the Nobeyama Telescope are transonic at 0.69 km s^{-1} ($\sigma_{\rm NT}/c_{\rm s} = 1.08$). We demonstrated that the larger line widths obtained by the single-dish telescope arose from unresolved sub-structures within their respective beams. The dispersions from larger scales σ_{ls} (as traced by the Nobeyama Telescope) can be decomposed into three components $\sigma^2_{\rm ls} = \sigma^2_{\rm ss} + \sigma^2_{\rm bm} + \sigma^2_{\rm rd}$, where small-scale σ_{ss} is the line dispersion of each ALMA beam, bulk motion σ_{bm} is dispersion between peak velocity of each ALMA beam, and σ_{rd} is the residual dispersion. Such decomposition, though purely empirical, appears to be robust throughout our data cubes. Apparent supersonic line widths, commonly found in massive molecular clouds, are thus likely due to the effect of poor spatial resolution. The observed non-thermal line dispersion (sometimes referred to as 'turbulence') transits from supersonic to subsonic at ~ 0.05 pc scales in OMC-2/3 region. Such transition could be commonly found with sufficient spatial (not just angular) resolution, even in regions with massive young clusters, such as Orion molecular clouds studied here.

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Filament Intersections and Cold Dense Cores in Orion A North

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We studied the filament structures and dense cores in OMC-2,3 region in Orion A North molecular cloud using the high-resolution N_2H^+ (1–0) spectral cube observed with the Atacama Large Millimeter/Submillimeter Array (ALMA). The filament network over a total length of 2 pc is found to contain 170 intersections and 128 candidate dense cores. The dense cores are all displaced from the infrared point sources (possible young stars), and the major fraction of cores (103) are located around the intersections. Towards the intersections, there is also an increasing trend for the total column density $N_{\rm tot}$ as well as the the power-law index of the column-density Probability Distribution Function (N-PDF), suggesting that the intersections would in general have more significant gas assembly than the other part of the filament paths. The virial analysis shows that the dense cores mostly have virial mass ratio of $\alpha_{\rm vir} = M_{\rm vir}/M_{\rm gas} < 1.0$, suggesting them to be bounded by the self gravity. In the mean time, only about 23 percent of the cores have critical mass ratio of $\alpha_{\rm crit} = M_{\rm crit}/M_{\rm gas} < 1.0$, suggesting them to be unstable against core collapse. Combining these results, it shows that the major fraction of the cold starless and possible prestellar cores in OMC-2,3 are being assembled around the intersections, and currently in a gravitationally bound state. But more extensive core collapse and star formation may still require continuous core-mass growth or other perturbation.

Accepted by MNRAS

http://arxiv.org/pdf/2006.13410

The Ophiuchus DIsc Survey Employing ALMA (ODISEA). II. The effect of stellar multiplicity on disc properties

Alice Zurlo[1,2], Lucas A. Cieza[1], Sebastián Pérez[3], Valentin Christiaens[4], Jonathan P. Williams[5] et al.

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We present Adaptive Optics (AO) near infrared (NIR) observations using VLT/NACO and Keck/NIRC2 of ODISEA targets. ODISEA is an ALMA survey of the entire population of circumstellar discs in the Ophiuchus molecular cloud. From the whole sample of ODISEA we select all the discs that are not already observed in the NIR with AO and that are observable with NACO or NIRC2. The NIR-ODISEA survey consists of 147 stars observed in NIR AO imaging for the first time, as well as revisiting almost all the binary systems of Ophiuchus present in the literature (20 out of 21). In total, we detect 20 new binary systems and one triple system. For each of them we calculate the projected separation and position angle of the companion, as well as their NIR and millimeter flux ratios. From the NIR contrast we derived the masses of the secondaries, finding that 9 of them are in the sub-stellar regime (30–50 $M_{\rm Jup}$). Discs in multiple systems reach a maximum total dust mass of $\sim$50 $M_{\oplus}$, while discs in single stars can reach a dust mass of 200 $M_{\oplus}$. Discs with masses above 10 $M_{\oplus}$ are found only around binaries with projected separations larger than $\sim$110 au. The maximum disc size is also larger around single star than binaries. However, since most discs in Ophiuchus are very small and low-mass, the effect of visual binaries is relatively weak in the general disc population.

Accepted by MNRAS

http://arxiv.org/pdf/2006.16259

Abstracts of recently accepted major reviews

From diffuse gas to dense molecular cloud cores

Javier Ballesteros-Paredes[1], Philippe André[2], Patrick Hennebelle[3], Ralf S. Klessen[4,5], Shu-ichiro Inutsuka et al.

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Molecular clouds are a fundamental ingredient of galaxies: they are the channels that transform the diffuse gas into stars. The detailed process of how they do it is not completely understood. We review the current knowledge of molecular clouds and their substructure from scales ∼1 kpc down to the filament and core scale. We first review the mechanisms of cloud formation from the warm diffuse interstellar medium down to the cold and dense molecular clouds, the process of molecule formation and the role of the thermal and gravitational instabilities. We also discuss the main physical mechanisms through which clouds gather their mass, and note that all of them may have a role at various stages of the process. In order to understand the dynamics of clouds we then give a critical review of the widely used virial theorem, and its relation to the measurable properties of molecular clouds. Since these properties are the tools we have for understanding the dynamical state of clouds, we critically analyse them. We finally discuss the ubiquitous filamentary structure of molecular clouds and its connection to prestellar cores and star formation.

Accepted by Space Science Reviews Topical collection "Star formation"

http://arxiv.org/pdf/2006.01326

Astrochemistry During the Formation of Stars

Jes K. Jørgensen[1], Arnaud Belloche[2] and Robin T. Garrod[3]

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Star-forming regions show a rich and varied chemistry, including the presence of complex organic molecules – both in the cold gas distributed on large scales, and in the hot regions close to young stars where protoplanetary disks arise. Recent advances in observational techniques have opened new possibilities for studying this chemistry. In particular, the Atacama Large Millimeter/submillimeter Array (ALMA) has made it possible to study astrochemistry down to Solar System size scales, while also revealing molecules of increasing variety and complexity. In this review, we discuss recent observations of the chemistry of star-forming environments, with a particular focus on complex organic molecules, taking context from the laboratory experiments and chemical models that they have stimulated. The key takeaway points are:

- The physical evolution of individual sources plays a crucial role in their inferred chemical signatures, and remains an important area for observations and models to elucidate.
- Comparisons of the abundances measured toward different star-forming environments (high-mass versus low-mass, Galactic center versus Galactic disk) reveal a remarkable similarity, an indication that the underlying chemistry is relatively independent of variations in their physical conditions.

- Studies of molecular isotopologs in star-forming regions provide a link with measurements in our own Solar System, and thus may shed light on the chemical similarities and differences expected in other planetary systems.

Accepted by Annual Reviews of Astronomy and Astrophysics

https://arxiv.org/pdf/2006.07071

The Origin of the Stellar Mass Distribution and Multiplicity

Yueh-Ning Lee[1], Stella S.R. Offner[2], Patrick Hennebelle[3], Philippe André[3], Hans Zinnecker et al.

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In this chapter, we review some historical understanding and recent advances on the Initial Mass Function (IMF) and the Core Mass Function (CMF), both in terms of observations and theories. We focus mostly on star formation in clustered environment since this is suggested by observations to be the dominant mode of star formation. The statistical properties and the fragmentation behaviour of turbulent gas is discussed, and we also discuss the formation of binaries and small multiple systems.

Accepted by Space Science Reviews

http://arxiv.org/pdf/2006.05778

Setting the Stage: Planet formation and Volatile Delivery

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The diversity in mass and composition of planetary atmospheres stems from the different building blocks present in protoplanetary discs and from the different physical and chemical processes that these experience during the planetary assembly and evolution. This review aims to summarise, in a nutshell, the key concepts and processes operating during planet formation, with a focus on the delivery of volatiles to the inner regions of the planetary system.

Accepted by Space Science Reviews

http://arxiv.org/pdf/2006.07127

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.

Traces of Planets imprinted in the Dust of Protoplanetary Disks

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Ph.D dissertation directed by: Oliver Gressel, Pablo Benítez-Llambay

Ph.D degree awarded: June 2020

When a molecular cloud collapses to form a star, not all material is accreted instantaneously. To conserve the total angular momentum of the system, a disk of rotating gas and dust is formed around the protostar, which then, slowly accretes onto the star. These disks represent the stage for planet formation. They are therefore product-oriented labelled protoplanetary disks (PPDs).

A very massive planet, such as Jupiter, displaces the material along its orbit by its gravitational influence. Consequently, it forms a gap in the disk - a ring-shaped area of depleted gas and dust material. This automatically divides the disk into an outer part and an inner part. While gas still flows from the outer region through the planetary gap towards the central star, the behaviour of dust grains is more ambiguous. We studied the effect of this gap onto radial dust transport by carrying out two-dimensional hydrodynamical simulations with the code FARGO3D, investigating, whether or not the solid material that is initially located in the outer parts of the disk is transported towards the inner system. We find that this mainly depends on the size of the dust grains and on the characteristics of the disk model. Yet, in all the cases, there is a critical grain size above which the dust is halted at the outer edge of the gap, where it starts to accumulate. Consequently, the inner system is depleted from these larger grains.

What we inferred from this allowed us to explain a long-known phenomenon in the Solar System - the absence of calcium-aluminium-rich inclusions (CAIs) in meteorites that originate from the inner Solar System. Motivated by our numerical results we found tiny CAIs in the meteorite NWA 5697, which is expected to have formed in the inner system. This detection supports the idea that large CAIs have been halted by Jupiter's presence in the outer system (where they are a common constituent of meteoritic bodies), and only small CAIs were permitted to be transported inwards.

In a further project, we investigated the dust structure if a Neptune-sized planet is embedded in the disk. In some cases, the planet induces three concentric rings to form in and around its orbit. We show that from the mutual spacing of these rings, one can infer the planet's migration behaviour. This can tells, whether and how a planet is changing its distance to the star in the PPD. Additionally, we performed radiative transfer simulations and image synthesis. This showed that the predicted effect is visible through highly resolved observations with the Atacama Milimeter-/Submillimeter Array (ALMA).

Five years after HL Tau: a new era in planet formation
Virtual conference, Dec 7 - Dec 11, 2020

Six years ago, somewhere in an email thread at the Joint ALMA Observatory:

Re: Suggestions for Science Verification targets for Long Baselines

HL Tau @ 04 31 38.45 +18:13:59.0
Band 6 total flux around 1 Jy. Observations would be continuum in whatever bands are available.

Band 3 might be most interesting to compare with the VLA data.

A few months after these words were written, the ALMA antennas pointed toward HL Tau, the first protoplanetary disk to be imaged with the ALMA long baselines. These observations marked the start of a revolution that has shaken the foundations of our understanding of planet formation and protoplanetary disk evolution. Now, 5 years after the publication of the iconic image of HL Tau, we aim to celebrate its anniversary with a conference that will discuss the most important advances in this new era in planet formation.

The conference will be online, and it will take place from Dec 7 to Dec 11, 2020. The conference will consist of a series of invited talks, live discussions, contributed talks (live or pre-recorded), and virtual posters. All talks will be recorded and made available to all the participants in order to facilitate discussions across different timezones. Registration will be free of charge. Pre-registration is now open, and the specific format and logistical details will be confirmed in the near future. The program will offer a broad view of the field, covering from the early stages of disks still embedded in their parental envelope to the times when full planetary systems are formed and only a few remnants of the progenitor disk are left. It will also explore the future of planet formation studies, as well as the impact and potential of upcoming instrumentation and telescopes (e.g. E-ELT, JWST), with particular focus on ngVLA. With this workshop, we aim at creating a more unified view of the exciting discoveries that have taken place in recent years. Some of the specific topics that will be discussed are:

- Planet formation in embedded protoplanetary disks
- Role and origin of disk substructures
- Dust evolution and planetesimal formation
- Disk polarization and magnetic fields
- Planet formation in multiple systems
- Chemistry in protoplanetary disks
- Protoplanetary disk demographics
- Disk evolution and dispersal
- Gas kinematics in protoplanetary disks
- Detection and characterization of young exoplanets and circumplanetary disks
- Debris disks

The list of confirmed invited speakers so far includes Nicolás Cuello, Barbara Ercolano, Meredith Hughes, Andrea Isella, Akimasa Kataoka, Anna Miotello, Paola Pinilla, Christophe Pinte, Didier Queloz, Patrick Sheehan, and Alice Zurlo.

More information can be found on our website: https://www.eso.org/sci/meetings/2020/hltau2020.html

LOC: Álvaro Ribas (co-chair), Antonio Hales (co-chair), Enrique Macías (co-chair), Bill Dent, Itziar de Gregorio-Monsalvo, John Carpenter, Julien Milli.

SOC: Álvaro Ribas (co-chair), Antonio Hales (co-chair), Enrique Macías (co-chair), John Carpenter (co-chair), Bill Dent, Catherine Espaillat, Inga Kamp, Itziar de Gregorio-Monsalvo, Joan Najita, Julien Milli, Laura Pérez, Lucas Cieza, Misato Fukagawa, Viviana Guzmán.

AGU Fall Meeting Session 'Accretion and differentiation of rocky planets: perspectives from geophysics, geochemistry, & astronomy'

We invite contributions to the session *Accretion and differentiation of rocky planets: perspectives from geophysics, geochemistry, & astronomy* at the AGU Fall Meeting from 7-11 December 2020, which will be at least partially virtual this year. We welcome contributions from all disciplines to advance the understanding of the formation and differentiation of rocky planets including, but not limited to, geochemistry, geophysics, cosmochemistry, planetary science, and astronomy. The AGU abstract portal is already open and the *deadline for submissions is Wednesday, 29 July*.

Session description: The simultaneous advent of high-resolution observations of planet-forming disks and enhanced prospects to characterize rocky exoplanets highlights the need for increasing interdisciplinary collaboration to understand the birth and life cycle of terrestrial worlds in our solar system and exoplanetary systems. Therefore, this session welcomes abstracts that address new observational, theoretical, and laboratory constraints on the formation of Earth and other terrestrial planets in the solar system as well as in exoplanetary systems. This includes modeling, observational, and experimental studies related to properties of planetesimals, impacts, pebble accretion, core segregation, moon formation, crust–mantle differentiation, atmosphere formation, or other major geophysical/geochemical/astronomical processes that fundamentally shape the evolution of rocky planetesimals and planets during their formation and early evolution.

Conveners: Laura Schaefer (Stanford), Rebecca Fischer (Harvard), Tim Lichtenberg (Oxford)

Invited Speakers: Jennifer Bergner (Chicago), Bethany Chidester (UC Davis)

Sections: Study of Earth's Deep Interior, Planetary Science, Mineral and Rock Physics

Themes: Origin and Evolution, Planetary Atmospheres, Planetary interiors, Planetary Geochemistry

https://agu.confex.com/agu/fm20/prelim.cgi/Session/101356

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.

Summary of Upcoming Meetings

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

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

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

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

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

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

IMPRS Summer School: Planet Formation in Protoplanetary Disks
31 Aug - 4 Sept 2020, Heidelberg, Germany
https://www.imprs-hd.mpg.de/Summer-School

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

Conditions and Impact of Star Formation - Across Times and Scales
28 September - 2 October 2020, Chile
https://astro.uni-koeln.de/symposium-star-formation-2020.html

From Clouds to Planets II: The Astrochemical Link
28 September - 2 October 2020, Berlin, Germany
https://events.mpe.mpg.de/event/12/

Five Years after HL Tau: A New Era in Planet Formation – VIRTUAL MEETING
7 - 11 December 2020, Chile
https://www.eso.org/sci/meetings/2020/hltau2020.html

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

Gordon Conference on Origins of Solar Systems
19 - 25 June 2021, MA, USA
https://www.grc.org/origins-of-solar-systems-conference/2021

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

Star Formation: From Clouds to Discs - A Tribute to the Career of Lee Hartmann
16 - 19 August 2021, Malahide, Ireland
https://www.dias.ie/cloudstodiscs/

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

Wheel of Star Formation: A conference dedicated to Prof. Jan Palouš
20 - 24 September 2020, Prague, Czech Republic
https://janfest2020.asu.cas.cz

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

From Clouds to Planets II: The Astrochemical Link
3 - 7 October 2022, Berlin, Germany
https://events.mpe.mpg.de/event/12/

Short Announcements

Galaxies is a peer-reviewed open access journal of astronomy, astrophysics, and cosmology published by the Multidisciplinary Digital Publishing Institute. It runs special issues to create collections of papers on specific topics led by Guest Editors.

The Special Issue **Star Formation in the Ultraviolet**

https://www.mdpi.com/journal/galaxies/special_issues/StarFormation

has come out as the Hubble Space Telescope (HST) is preparing to devote 1000 orbits to obtain a *UV Legacy Library of Young Stars as Essential Standards (ULLYSES)* with UV spectroscopy of both low mass T Tauri stars (500 orbits) and 500 orbits for massive OB stars that provide the UV radiation in Extra-galactic star formation regions.

These are the review articles:

1. Overview: Star Formation in the Ultraviolet - Jorick S. Vink (Guest Editor)
2. The UV Perspective of Low-Mass Star Formation - Schneider, Günther & France
3. On the mass accretion rates of Herbig Ae/Be stars - Ignacio Mendigutia
4. UV Spectroscopy of massive stars - John Hillier
5. Massive Star Formation in the Ultraviolet observed with HST - Claus Leitherer
6. Applications of Stellar Population Synthesis in the Distant Universe - Elizabeth Stanway

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