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

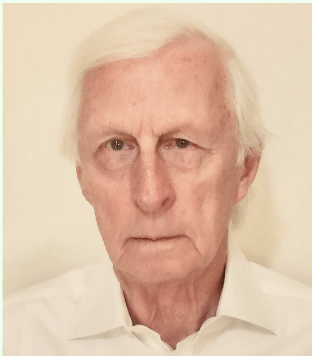
V1647 Ori erupted in late 2003, and illuminated a large outflow cavity. The nature of V1647 Ori has been extensively debated, some features point to a FUor eruption, while the emission-line spectrum suggests an EXor. It is likely that this contradictory evidence can be reconciled if V1647 Ori is an unresolved binary, with one component undergoing a FUor eruption, while the other is an active emission-line star.
Image obtained with GMOS on Gemini-North, from Reipurth & Aspin (2004).

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/starformation/index.cfm

Leonard Kuhi

in conversation with Bo Reipurth



Q: *You did your thesis work at Lick Observatory in the 1960s with George Herbig, which must have been a unique experience. What are your recollections of that time?*

A: I would say that George was not a hands-on graduate adviser, but interactions with him were always productive. I first worked for him as a summer student at Lick on Mt. Hamilton. He had taken a series of photographs of the NGC 2068 region with the slitless grating spectrograph on the Crossley reflector. A filter of about 400 Å centered on Hα allowed one to find emission-line stars. That led to the only paper we wrote together (1963), although I recall that he did most of the writing. The paper reported on 45 new Hα emission stars that were T Tauri stars and one Herbig-Haro object, HH24, that was a barely detectable smudge on the photographic plate. I was blown away by the Gemini and Hubble images of HH24 that were published a few years ago. They showed the incredible complexity of that object with its highly collimated polar jets and surrounding nebulosity. My thesis work was done on Mt. Hamilton in 1962-63. I and my wife lived on the mountain as did everyone else. We were fortunate to move into a small cottage (long since demolished) in the shadow of the 3 meter dome for 18 months.

I think that George was very loath to take credit for his students' thesis work. He felt that the dissertation was the students project and he just provided some guidance along the way. Sometimes he might have suggested a possible direction of research but he would not be a co-author unless it was truly a joint research project. He was very modest and unassuming. He instructed me in the use of the coudé spectrograph of the Lick 3 meter (at that time the second largest optical telescope in the world and less than three years old) and then left me pretty much alone to make the observations and do the work. During my thesis work we met semi-regularly and he usually had good suggestions to make and insightful questions to ask. But he did not insist on controlling the research. One thing that really impressed me about George was his meticulous attention to detail, not only in his research and papers, but especially in the use of the telescopes and spectrographs at Lick. Everything was spotless and tuned to maximum performance. That included me![1]

Q: *What were the key ideas behind your dissertation?*

A: George had obtained several high dispersion (16 and 10 Å/mm) spectra of six T Tauri stars which he gave to me to develop a model that could be used to estimate mass loss rates from the emission line profiles of hydrogen and CaII. The profiles had some P Cygni characteristics, namely an absorption component on the shortward side of the emission peak. LkHα 120 was especially notable with a very deep absorption feature that went below the continuum. Other stars showed double-peaked profiles or even fairly symmetric ones. My goal was to put the mass outflow interpretation on a sounder footing and extend the calculations to more stars. I used a very simplistic model with material being ejected from the surface by some unknown mechanism but acted on only by gravity. Of course everything was assumed to be spherically symmetric. The emitting region was assumed to be ionized hydrogen surrounded by a neutral region that produced the violet displaced absorption components. There were quite a few other assumptions necessary to get the model to work but the physical parameters were determined from the stellar spectra. The emission line profiles were calculated by integrating over the constant line-of-sight velocity surfaces producing an intensity for each frequency point of the profile. The ejection velocities of a few 100 km/s were measured from the width of the observed line profiles. The average mass-loss rate was about 4×10^{-8} $M_\odot$/yr. From the admittedly poor statistics of the properties of known T Tauri stars at the time it was estimated that at any one epoch about 40% of the contracting stars may be losing mass. The mass loss could result in about a 10% decrease of the contraction time to the main sequence and the loss of a significant fraction of the star's initial mass.

But spherically symmetric models are notoriously unrealistic and the first to fall by the wayside. Several years later Roger Ulrich produced some of the emission line profiles with an asymmetric infall model. He and Gillian Knapp then obtained higher resolution image tube spectra of many more T Tauri stars. They used the NaI D line profiles as a true indicator of the velocity field. They compared those profiles to the hydrogen emission line profiles which ranged from symmetric to double peaked to classical P Cygni profiles. They found that the only true

[1] Adapted from "George Herbig and Early Stellar Evolution" by Bo Reipurth (http://ifa.hawaii.edu/SP1)

indicator of outflow were P Cygni profiles in which the absorption component went below the continuum. Double peaked profiles were ambiguous and could indicate inflow or outflow. Symmetric profiles were likely chromospheric in origin with no significant flow. Their results were a very convincing demonstration of the dangers of simplistic assumptions in the interpretation of emission line spectra.

Q: *In 1977 you published with Martin Cohen a study of the young star PV Cep. What was unusual about this object?*

A: Martin had been looking for faint nebulous objects on the Palomar Sky Survey and PV Cep was one such object found in the region of NGC 7023. What was remarkable was that the streak observed on the Palomar photos had disappeared and was replaced by a much smaller fan-shaped nebula. The associated star had increased in brightness by a few magnitudes. We followed up that discovery with four years of spectral observations that indicated enormous variability (up to four magnitudes in the red!) and a rich emission line spectrum similar to the most extreme T Tauri stars. Strong P Cygni profiles (comparable to those of LkHα 120) were observed at Hα and NaI D (a strong indicator of outflow) when the star was at its brightest but disappeared when it was faint. The nebular forbidden line spectrum indicated a lack of spherical symmetry. PV Cep was a very complex object! We interpreted it as a T Tauri star that had just recently broken through its circumstellar cocoon at a time when the star is characterized by a strong stellar wind and highly irregular variability.

Q: *You co-authored the famous Cohen-Kuhi paper from 1979, which with 1300 citations is among the most cited papers ever on young stars. How did that project start, and what were the main conclusions?*

A: That paper was truly our magnum opus. The project was an attempt to obtain basic data such as spectral types, emission line strengths, bolometric luminosities and effective temperatures of a large enough sample of late type emission stars to be able to draw more definitive conclusions about the PMS stage of stellar evolution. We obtained low resolution spectra of about 500 Hα emission stars in the Herbig and Rao compilation using the original Hα surveys so that we could construct HR diagrams for the Taurus-Auriga complex, Orion, NGC 2264, NGC 7000/IC 5070 and the Rho Ophiuchi association. What made it all possible was the development of the image tube image dissector scanner by Joe Wampler. The scanner used the phosphor of the image tube as a short term storage device and produced real time buildup of the spectrum so that one could determine when an adequate signal to noise ratio had been reached. The computer controlled scanner had a resolution of 7 Å and allowed us to obtain viable spectra of stars with V=18 in about 40 minutes with the Lick 3 meter telescope. The optical spectra were augmented by infrared data from Martin's Mt. Lemmon observations and various other sources to estimate the total luminosity after appropriate reddening corrections were applied. Comparison of the observational HR diagram to theoretical convective-radiative evolutionary tracks led to the inescapable conclusion that T Tauri stars are pre-main sequence objects located primarily on the convective tracks or on the early part of the radiative tracks for low mass stars. Three parameters that described the properties of stellar groups are the proportion of stars on the convective tracks, the proportion having strong emission line spectra and the growth rate for star formation. These indicated that the Taurus-Auriga group is clearly the youngest and most active, Orion is a bit older and NGC 2264 is the oldest and least active. Typical radii were in the range 1 to 5 solar radii, the masses from 0.2 to 3 solar masses, the spectral types from K0 to M5.5 (the present spectral classification scheme for cool stars was introduced many years later), the luminosity classes V to III and the ages from 10^4 to $6{\times}10^6$ years. There was no evidence to support coeval star formation: the age spread indicated that formation was continuous in each stellar group. The three most completely observed groups show a mass function consistent with the Salpeter initial mass function. We estimated the efficiency of star formation from the ratio of the mass in stars to total gas mass: 5 to 10%. More than half of the T Tauri stars showed infrared excesses explicable only as thermal emission from dust grains, presumably left over from the star formation process. The correlation of the luminosity with emission line strength suggested that the excitation mechanism becomes less effective with age. It also seemed that the closely nebulous stars were the youngest in each group. The project involved an enormous amount of observing time since the spectra of each star had to be obtained individually. I would be remiss not to say that many other people contributed in various ways to this work for which we were very grateful.

Q: *A few years later Stuart Vogel and you published a study of the rotational velocities of PMS stars. How did that fit in with what was known at the time?*

A: We studied a selection of PMS stars in the Taurus-Auriga group and in NGC 2264 using moderate resolution spectra obtained with the Carnegie image tube spectrograph of the 4 meter telescope at KPNO and with the Varo image tube system at the coudé spectrograph of the Lick 3 meter reflector. The study was confined to those stars showing an absorption line spectrum and hence excluded the heavily veiled T Tauri stars with strong emission lines. The absorption lines are photospheric in origin and reflective of what is happening at the surface of the star as well as being broadened by its rotation. Emission lines could not be used to determine rotation without a very detailed model for their origin. We used a Fourier transform technique that made use of all the absorption lines in a narrow spectral range rather than using the usual technique of fitting individual absorption line profiles with theoretical profiles. Division of the Fourier transform of the spectrum of a rotating star by that of a standard star of the same spectral type ultimately leads to the rotational velocity v sin$i$.

The results were a bit surprising: the velocities showed an interesting bifurcation on the HR diagram. For radiative track stars of mass 1.5 $M_\odot$ the velocities are generally 25 km/s (our measurement limit) whereas the more massive stars had velocities up to 150 km/s. Most stars on the convective tracks and most Hα emission stars had rotational velocities of less than 35 km/s. There was no correlation between v sin$i$ and emission line strength for stars showing a photospheric spectrum. We could not say anything about the rotation of the very strongest emission line stars. These results were in direct contrast to the widely accepted idea that T Tauri stars were all rapid rotators, a conclusion that was based on the earlier results of 18 to 70 km/s by Herbig for four of the brightest T Tauri stars. Our results indicated that by the time T Tauri stars showed a photospheric absorption spectrum the angular momentum problem (main sequence low mass stars rotate very slowly) had been solved with most of the angular momentum loss likely taking place during the initial evolution onto or along the convective track. Our resolution wasn't high enough to say anything about the change in rotational velocity along the radiative tracks. Later studies by Hartmann and others confirmed and extended our conclusions to detection limits of 10 km/s much to my relief since we were really pushing the limits at that time.

Q: *In the early 1980s, Fred Walter and you published early X-ray observations on young stars. What were the main conclusions?*

A: We detected soft X-rays from 10 T Tauri stars in our sample of 23 stars with the Einstein X-ray telescope Image Proportional Counter. We found an inverse correlation between the X-ray flux and the Hα emission line strength. We thought the X-rays originated in a solar type corona but with the added feature of the presence of dust grains absorbing the X-rays in the strong Hα emission stars. We called it the "smothered corona". We also searched for X-ray variability in followup observations of 14 PMS stars. The previous X-ray emission from AA Tau had disappeared, a flare was detected in AS 205 and significant variation was observed in four other stars. Most stars showed no detectable X-ray variability. The disappearance of X-rays from AA Tau could be explained by the smothered corona model but the flare in AS 205 was very similar to solar X-ray flares which do not involve any dust. Later observations with more sensitivity by Montmerle and others detected X-rays in many more PMS stars and were better able to understand their behavior.

Q: *You have served in a number of administrative positions in academia. Please tell about this aspect of your career.*

A: I was first the Dean of Physical Sciences and then the Provost and Dean of the College of Letters and Science at Berkeley from the late 70's to 1989. In those days AURA had two representatives from each member institution: an astronomer and an administrator. Geoff Burbidge nominated me as the administrator so the University of California ended up with two astronomers on the AURA Board. As AURA grew, institutions ended up with only one representative but more campuses of the University of California became members. I served on the AURA Board for many years as a representative from Berkeley and later from Minnesota. I also had my turn chairing the AURA Board. It was a very exciting time getting the Space Telescope Science Institute established with Riccardo Giacconi as the first permanent director. It seemed that every week there was another issue to be resolved.

The other exciting development during my time on the Board was the design and construction of the Gemini telescopes. I was able to attend the dedication of Gemini North on Mauna Kea many years ago. As Dean and Provost at Berkeley I played a small role in two astronomy developments: I was able to provide significant funding for part of Berkeley's contribution to the Berkeley Illinois Maryland radio telescope array. It had ten antennas located at the UCB Hat Creek Observatory and was the premier imaging instrument in the world at millimeter wavelengths.

At that time I also was persuaded by Dave Cudaback and Jerry Nelson to present Jerry's ideas for a low cost segmented ten meter telescope to our chancellor at Berkeley who supported the proposal to the president of the University of California. Jerry's plan was to build a 10 meter telescope with a mosaic primary mirror made up of 36 hexagonal mirror segments each 1.8 meters in diameter. The segments would be actively controlled to maintain the required parabolic shape of the primary mirror. The telescope became a joint project with CalTech and ultimately two 10 meter segmented telescopes funded by Keck were built on Mauna Kea. I was part of the negotiating team that set up the original operational agreement between CalTech and the University of California.

When I was Vice President of the University of Minnesota I helped raise the funds to allow Minnesota to join the Large Binocular Telescope consortium led by the University of Arizona. The twin 8 meter telescope was an amazing project to see carried to completion.

Abstracts of recently accepted papers

Magnetic field in a circumbinary disk around a Class I YSO

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Polarized continuum emission at millimeter/sub-millimeter wavelengths is usually attributed to thermal emission from dust grains aligned through radiative torques with the magnetic field. However, recent theoretical work has shown that under specific conditions polarization may arise from self-scattering of thermal emission and by radiation fields from a nearby stellar object. We use multi-frequency polarization observations of a circumbinary disk to investigate how the polarization properties change at distinct frequency bands. Our goal is to discern the main mechanism responsible for the polarization through comparison between our observations and model predictions for each of the proposed mechanisms. We used the Atacama Large Millimeter/submillimeter Array to perform full polarization observations at 97.5 GHz (Band 3), 233 GHz (Band 6) and 343.5 GHz (Band 7). The ALMA data have a mean spatial resolution of 28 AU. The target is the Class I object BHB07-11, which is the youngest object in the Barnard 59 protocluster. Complementary Karl G. Jansky Very Large Array observations at 34.5 GHz were also performed and revealed a binary system at centimetric continuum emission within the disk. We detect an extended and structured polarization pattern remarkably consistent among all three bands. The distribution of polarized intensity resembles a horseshoe shape with polarization angles following this morphology. From the spectral index between bands 3 and 7, we derive a dust opacity index $\beta \sim 1$ consistent with maximum grain sizes larger than expected to produce self-scattering polarization in each band. The polarization morphology and the polarization levels do not match predictions from self-scattering. On the other hand, marginal correspondence is seen between our maps and predictions from radiation field assuming the brightest binary component as main radiation source. Previous molecular line data from BHB07-11 indicates disk rotation. We used the DustPol module of the ARTIST radiative transfer tool to produce synthetic polarization maps from a rotating magnetized disk model assuming combined poloidal and toroidal magnetic field components. The magnetic field vectors (i. e., the polarization vectors rotated by 90°) are better represented by a model with poloidal magnetic field strength about 3 times the toroidal one. The similarity of our polarization patterns among the three bands provides a strong evidence against self-scattering and radiation fields. On the other hand, our data are reasonably well reproduced by a model of disk with toroidal magnetic field components slightly smaller than poloidal ones. The residual is likely due to the internal twisting of the magnetic field due to the binary system dynamics, which is not considered in our model.

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http://arxiv.org/pdf/1805.00494

How much does turbulence change the pebble isolation mass for planet formation?

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When a planet becomes massive enough, it gradually carves a partial gap around its orbit in the protoplanetary disk. A pressure maximum can be formed outside the gap where solids that are loosely coupled to the gas, typically in the pebble size range, can be trapped. The minimum planet mass for building such a trap, which is called the pebble isolation mass (PIM), is important for two reasons: it marks the end of planetary growth by pebble accretion, and the trapped dust forms a ring that may be observed with millimetre observations. We study the effect of disk turbulence on the pebble isolation mass and find its dependence on the gas turbulent viscosity, aspect ratio, and particles Stokes number. By means of 2D gas hydrodynamical simulations, we found the minimum planet mass to form a radial pressure maximum beyond the orbit of the planet, which is the necessary condition to trap pebbles. We then carried out 2D gas plus dust hydrodynamical simulations to examine how dust turbulent diffusion impacts particles trapping at the pressure maximum. We finally provide a semi-analytical calculation of the PIM based on comparing the radial drift velocity of solids and the root mean square turbulent velocity fluctuations around the pressure maximum. From our results of gas simulations, we provide an expression for the PIM versus disk aspect ratio and turbulent viscosity. Our gas plus dust simulations show that the effective PIM can be nearly an order of magnitude larger in high-viscosity disks because turbulence diffuse particles out of the pressure maximum. This is quantified by our semi-analytical calculation, which gives an explicit dependence of the PIM with Stokes number of particles. We conclude than disk turbulence can significantly alter the PIM, depending on the level of turbulence in regions of planet formation.

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http://arxiv.org/pdf/1804.00924

Planet-driven spiral arms in protoplanetary disks: II. Implications

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We examine whether various characteristics of planet-driven spiral arms can be used to constrain the masses of unseen planets and their positions within their disks. By carrying out two-dimensional hydrodynamic simulations varying planet mass and disk gas temperature, we find that a larger number of spiral arms form with a smaller planet mass and a lower disk temperature. A planet excites two or more spiral arms interior to its orbit for a range of disk temperature characterized by the disk aspect ratio $0.04 \leq (h/r)_p \leq 0.15$, whereas exterior to a planet's orbit multiple spiral arms can form only in cold disks with $(h/r)_p \lesssim 0.06$. Constraining the planet mass with the pitch angle of spiral arms requires accurate disk temperature measurements that might be challenging even with ALMA. However, the property that the pitch angle of planet-driven spiral arms decreases away from the planet can be a powerful diagnostic to determine whether the planet is located interior or exterior to the observed spirals. The arm-to-arm separations increase as a function of planet mass, consistent with previous studies; however, the exact slope depends on disk temperature as well as the radial location where the arm-to-arm separations are measured. We apply these diagnostics to the spiral arms seen in MWC 758 and Elias 2–27. As shown in Bae et al. (2017), planet-driven spiral arms can create concentric rings and gaps, which can produce more dominant observable signature than spiral arms under certain circumstances. We discuss the observability of planet-driven spiral arms versus rings and gaps.

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Low levels of methanol deuteration in the high-mass star-forming region NGC 6334I

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The abundance of deuterated molecules in a star-forming region is sensitive to the environment in which they are formed. Deuteration fractions therefore provide a powerful tool for studying the physical and chemical evolution of a star-forming system. While local low-mass star-forming regions show very high deuteration ratios, much lower fractions are observed towards Orion and the Galactic Centre. We derive methanol deuteration fractions at a number of locations towards the high-mass star-forming region NGC 6334I, located at a mean distance of 1.3 kpc, and discuss how these can shed light on the conditions prevailing during its formation. We use high sensitivity, high spatial and spectral resolution observations obtained with ALMA to study transitions of the less abundant, optically thin, methanol-isotopologues: (13)CH_3OH, $CH_3{}^{18}OH$, CH_2DOH and CH_3OD, detected towards NGC 6334I. Assuming LTE and excitation temperatures of 120–330 K, we derive column densities for each of the species and use these to infer CH_2DOH/CH_3OH and CH_3OD/CH_3OH fractions. Interestingly, the column densities of CH_3OD are consistently higher than those of CH_2DOH throughout the region. All regions studied in this work show CH_2DOH/CH_3OH as well as CH_2DOH/CH^3OD ratios that are considerably lower than those derived towards low-mass star-forming regions and slightly lower than those derived for the high-mass star-forming regions in Orion and the Galactic Centre. The low ratios indicate a grain surface temperature during formation ∼30 K, for which the efficiency of the formation of deuterated species is significantly reduced.

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The ALMA-PILS survey: Complex nitriles towards IRAS 16293–2422

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Complex organic molecules are readily detected in the inner regions of the gaseous envelopes of forming protostars. In particular, molecules that contain nitrogen are interesting due to the role nitrogen plays in the development of life and the compact scales such molecules have been found to trace around forming protostars. The goal of this work is to determine the inventory of one family of nitrogen-bearing organic molecules, complex nitriles (molecules with a −CN functional group) towards two hot corino sources in the low-mass protostellar binary IRAS 16293−2422. This work explores the abundance differences between the two sources, the isotopic ratios, and the spatial extent derived from molecules containing the nitrile functional group. Using data from the Protostellar Interferometric Line Survey (PILS) obtained with ALMA we determine abundances and excitation temperatures for the detected nitriles. We also present a new method for determining the spatial structure of sources with high line density and large velocity gradients — Velocity-corrected INtegrated emission (VINE) maps. We detect methyl cyanide (CH_3CN) as well as 5 of its isotopologues, including the detection of CHD_2CN which is the first detection in the ISM. We also detect ethyl cyanide (C_2H_5CN), vinyl cyanide (C_2H_3CN), and cyanoacetylene (HC_3N). We find that abundances are similar between IRAS 16293A and IRAS 16293B on small scales except for vinyl cyanide which is only detected towards the latter source. This suggests an important difference between the sources either in their evolutionary stage or warm-up

timescales. We also detect a spatially double-peaked emission for the first time in molecular emission in the A source, suggesting that this source is showing structure related to a rotating toroid of material.

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An inner warp in the DoAr 44 T Tauri transition disk

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Optical/IR images of transition disks (TDs) have revealed deep intensity decrements in the rings of HAeBes HD142527 and HD100453, that can be interpreted as shadowing from sharply tilted inner disks, such that the outer disks are directly exposed to stellar light. Here we report similar dips in SPHERE+IRDIS differential polarized imaging (DPI) of T Tauri DoAr44. With a fairly axially symmetric ring in the submm radio continuum, DoAr44 is likely also a warped system. We constrain the warp geometry by comparing radiative transfer predictions with the DPI data in H band ($Q_\phi(H)$) and with a re-processing of archival 336 GHz ALMA observations. The observed DPI shadows have coincident radio counterparts, but the intensity drops are much deeper in $Q_\phi(H)$ (∼88%), compared to the shallow drops at 336 GHz (∼24%). Radiative transfer predictions with an inner disk tilt of ∼30°±5° approximately account for the observations. ALMA long-baseline observations should allow the observation of the warped gas kinematics inside the cavity of DoAr44.

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Infall and Outflow Motions towards a Sample of Massive Star Forming Regions from the RMS Survey

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We present the results of an outflow and infall survey towards a distance limited sample of 31 massive star forming regions drawn from the RMS survey. The presence of young, active outflows is identified from SiO (8-7) emission and the infall dynamics are explored using $HCO^+/H^{13}CO^+$ (4-3) emission. We investigate if the infall and outflow parameters vary with source properties, exploring whether regions hosting potentially young active outflows show similarities or differences with regions harbouring more evolved, possibly momentum driven, "fossil" outflows. SiO emission is detected towards approximately 46% of the sources. When considering sources with and without an SiO detection (i.e. potentially active and fossil outflows respectively), only the ^{12}CO outflow velocity shows a significant difference between samples, indicating SiO is more prevalent towards sources with higher outflow velocities. Furthermore, we find the SiO luminosity increases as a function of the *Herschel* 70 μm to *WISE* 22μm flux ratio, suggesting the production

of SiO is prevalent in younger, more embedded regions. Similarly, we find tentative evidence that sources with an SiO detection have a smaller bolometric luminosity-to-mass ratio, indicating SiO (8-7) emission is associated with potentially younger regions. We do not find a prevalence towards sources displaying signatures of infall in our sample. However, the higher energy HCO^+ transitions may not be the best suited tracer of infall at this spatial resolution in these regions.

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The low-mass pre-main-sequence population of Sco OB1

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The low-mass members of OB associations, expected to be a major component of their total population, are in most cases poorly studied because of the difficulty of selecting these faint stars in crowded sky regions. Our knowledge of many OB associations relies only on a relatively small number of massive members. We study here the Sco OB1 association, with the aim of a better characterization of its properties such as global size and shape, member clusters and their morphology, age and formation history, and total mass. We use deep optical and NIR photometry from the VPHAS$^+$ and VVV surveys, over a wide area ($2.6° \times 2.6°$), complemented by Spitzer IR data, and Chandra and XMM-Newton X-ray data. A new technique is developed to find clusters of pre-main-sequence M-type stars using suitable color-color diagrams, which complements existing selection techniques using narrow-band H-α photometry or NIR and UV excesses, and X-ray data. We find a large population of approximately 4000 candidate low-mass Sco OB1 members, net of field-star contaminations, whose spatial properties correlate well with those of Hα-emission, NIR-excess, UV-excess, and X-ray detected members, and unresolved X-ray emission. The low-mass population is spread among several interconnected subgroups: they coincide with the HII regions G345.45+1.50 and IC4628, and the rich clusters NGC 6231 and Trumpler 24, with an additional subcluster intermediate between these two. The total mass of Sco OB1 is estimated to be 8500 $M_\odot$. Indication of a sequence of star-formation events is found, from South (NGC 6231) to North (G345.45+1.50). We suggest that the diluted appearance of Trumpler 24 indicates that the cluster is now dissolving into the field, and that tidal stripping by NGC 6231 nearby contributes to the process.

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Evolutionary Status of T Tauri Stars

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The problem of the determination of T Tauri stars masses and ages using their evolutionary status is discussed. We test of pre-main sequence evolutionary models of D'Antona & Mazzitelli (1994), Dotter et al. (2008), Bressan et al. (2012) and Chen et al. (2014), Baraffe et al. (2015) using well determined observational parameters of 12 binary T Tauri stars (TTS) and 2 binary red dwarfs. It is shown that the masses derived using the tracks of all models are in good agreement with the masses obtained from the observations of TTS with masses $M > 0.7\ M_\odot$ (mean error $\epsilon \sim 10\%$). Low-mass stars with $M \leq 0.7\ M_\odot$ have significantly greater mean error: $\epsilon \sim 50\%$ for the tracks of Bressan et al. and Chen et al. and $\epsilon \sim 30\%$ for the other tracks. The isochrones of all tested evolutionary models diverge for the stars with masses $M \leq 0.7\ M_\odot$. The difference increases with the mass decrease and can reach 10% of Kelvin-Helmholtz time for stars with mass $M = 0.2\ M_\odot$. The ages of most of the considered T Tauri stars are smaller than the Kelvin-Helmholtz time. This confirms their evolutionary status of pre-main sequence stars.

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SOLIS IV. Hydrocarbons in the OMC-2 FIR 4 region, a probe of energetic particle irradiation of the region

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We report new interferometric images of cyclopropenylidene, c-C_3H_2, towards the young protocluster OMC-2 FIR 4. The observations were performed at 82 and 85 GHz with the NOrthern Extended Millimeter Array (NOEMA) as part of the project Seeds Of Life In Space (SOLIS). In addition, IRAM-30m data observations were used to investigate the physical structure of OMC-2 FIR 4. We find that the c-C_3H_2 gas emits from the same region where previous SOLIS observations showed bright HC_5N emission. From a non-LTE analysis of the IRAM-30m data, the c-C_3H_2 gas has an average temperature of ∼40K, a H_2 density of $\sim 3 \times 10^5$ cm^{-3}, and a c-C_3H_2 abundance relative to H_2 of (7±1) $\times 10^{-12}$. In addition, the NOEMA observations provide no sign of significant c-C_3H_2 excitation temperature gradients across the region (about 3–4 beams), with Tex in the range 8±3 up to 16±7K. We thus infer that our observations are inconsistent with a physical interaction of the OMC-2 FIR 4 envelope with the outflow arising from OMC-2 FIR 3, as claimed by previous studies. The comparison of the measured c-C_3H_2 abundance with the predictions from an astrochemical PDR model indicates that OMC-2 FIR 4 is irradiated by a FUV field ∼1000 times larger than the interstellar one, and by a flux of ionising particles ∼4000 times larger than the canonical value of 1×10^{-17} s^{-1} from the Galaxy cosmic rays, which is consistent with our previous HC_5N observations. This provides an important and independent confirmation of other studies that one or more sources inside the OMC-2 FIR 4 region emit energetic (≥10 MeV) particles.

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An ALMA 3mm continuum census of Westerlund 1

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Massive stars play an important role in both cluster and galactic evolution and the rate at which they lose mass is a key driver of both their own evolution and their interaction with the environment up to and including their

SNe explosions. Young massive clusters provide an ideal opportunity to study a co-eval population of massive stars. We performed 3mm continuum observations with the Atacama Large Millimetre/submillimetre Array of the Galactic cluster Westerlund 1, to study the constituent massive stars and determine mass-loss rates for the diverse post-main sequence population.
We detected emission from 50 stars in Westerlund 1, comprising all 21 Wolf-Rayets within the field of view, eight cool and 21 OB super-/hypergiants. Emission nebulae were associated with a number of the cool hypergiants while, unexpectedly, a number of hot stars also appear spatially resolved. We measured the mass-loss rates for a unique population of massive post-main sequence stars at every stage of evolution, confirming a significant increase as stars transition from OB supergiant to WR states. The range of spectral types exhibited provides a critical test of radiatively driven wind theory and the reality of the bi-stability jump. The extreme mass-loss rate inferred for the interacting binary Wd1-9 in comparison to other cluster members confirmed the key role binarity plays in massive stellar evolution. The presence of compact nebulae around a number of OB and WR stars is unexpected; by analogy to the cool super-/hypergiants we attribute this to confinement and sculpting of the stellar wind via interaction with the intra-cluster medium/wind. Given the morphology of core collapse SNe depend on the nature of the pre-explosion circumstellar environment, if this hypothesis is correct then the properties of the explosion depend not just on the progenitor, but also the environment in which it is located.

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Fragmentation properties of massive protocluster gas clumps: an ALMA study

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Fragmentation of massive dense molecular clouds is the starting point in the formation of rich clusters and massive stars. Theory and numerical simulations indicate that the population of the fragments (number, mass, diameter, separation) resulting from the gravitational collapse of such clumps is probably regulated by the balance between the magnetic field and the other competitors of self-gravity, in particular turbulence and protostellar feedback. We have observed 11 massive, dense and young star-forming clumps with the Atacama Large Millimeter Array (ALMA) in the thermal dust continuum emission at ?1 mm with an angular resolution of 0.25 arcseconds with the aim of determining their population of fragments. We find fragments on sub-arcsecond scales in 8 out of the 11 sources. The ALMA images indicate two different fragmentation modes: a dominant fragment surrounded by companions with much smaller mass and size, and many (8) fragments with a gradual change in masses and sizes. On average, the largest number of fragments is found towards the warmer and more massive clumps. Also, the warmer clumps tend to form fragments with larger mass and size. To understand the role of the different physical parameters to regulate the final population of the fragments, we have simulated the collapse of a massive clump of 100 and 300 solar masses having different magnetic support. The simulations indicate that: (1) fragmentation is inhibited when the initial turbulence is low, independent of the other physical parameters. (2) a filamentary distribution of the fragments is favoured in a highly magnetised clump. We conclude that the clumps that show many fragments distributed in a filamentary-like structure are likely characterised by a strong magnetic field, while the others are possible also in a weaker magnetic field.

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A survey for variable young stars with small telescopes: First results from HOYS-CAPS

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Variability in Young Stellar Objects (YSOs) is one of their primary characteristics. Long-term, multi-filter, high-cadence monitoring of large YSO samples is the key to understand the partly unusual light-curves that many of these objects show. Here we introduce and present the first results of the HOYS-CAPS citizen science project which aims to perform such monitoring for nearby ($d < 1$ kpc) and young (age < 10 Myr) clusters and star forming regions, visible from the northern hemisphere, with small telescopes. We have identified and characterised 466 variable (413 confirmed young) stars in 8 young, nearby clusters. All sources vary by at least 0.2 mag in V, have been observed at least 15 times in V, R and I in the same night over a period of about 2 yrs and have a Stetson index of larger than 1. This is one of the largest samples of variable YSOs observed over such a time-span and cadence in multiple filters. About two thirds of our sample are classical T-Tauri stars, while the rest are objects with depleted or transition disks. Objects characterised as bursters show by far the highest variability. Dippers and objects whose variability is dominated by occultations from normal interstellar dust or dust with larger grains (or opaque material) have smaller amplitudes. We have established a hierarchical clustering algorithm based on the light-curve properties which allows the identification of the YSOs with the most unusual behaviour, and to group sources with similar properties. We discuss in detail the light-curves of the unusual objects V2492 Cyg, V350 Cep and 2MASS J21383981+5708470.

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BANYAN. XII. New Members of Nearby Young Associations from Gaia-Tycho Data

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We present a search for stellar members of young associations within 150 pc of the Sun based on Gaia-Tycho and an updated version of the BANYAN Σ software to determine Bayesian membership probabilities that includes Gaia-2MASS color-magnitude diagrams. We identify 32 new F0–M3-type bona fide members of the 10–200 Myr-old Sco-Cen, Carina, Tucana-Horologium, Columba and Octans associations and the AB Doradus, β Pictoris and Carina-Near moving groups. These new bona fide members have measurements of their full kinematics and literature data consistent with a young age. We also confirm the membership of 66 previously known candidate members using their Gaia-Tycho trigonometric distances or new literature radial velocities, and identify 219 additional new candidate members, most of which do not yet have a radial velocity measurement. This work is the first step towards a completeness-corrected survey of young association members based on Gaia-DR2 in the near future.

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SMA observations of the polarized dust emission in solar-type Class 0 protostars: the magnetic field properties at envelope scales

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Although, from a theoretical point of view, magnetic fields are believed to have a significant role during the early stages of star formation, especially during the main accretion phase, the magnetic field strength and topology is poorly constrained in the youngest accreting Class 0 protostars that lead to the formation of solar-type stars. We carried out observations of the polarized dust continuum emission with the SMA interferometer at 0.87mm, in order to probe the structure of the magnetic field in a sample of 12 low-mass Class 0 envelopes, including both single protostars and multiple systems, in nearby clouds. Our SMA observations probe the envelope emission at scales 600 ? 5000 au with a spatial resolution ranging from 600 to 1500 au depending on the source distance. We report the detection of linearly polarized dust continuum emission in all of our targets, with average polarization fractions ranging from 2protostellar envelopes. The polarization fraction decreases with the continuum flux density, which translates into a decrease with the H2 column density within an individual envelope. Our analysis show that the envelope-scale magnetic field is preferentially observed either aligned or perpendicular to the outflow direction. The alignment of the outflowing gas and the magnetic field does not seem to depend on the polarization fraction nor polarized intensity in our sample of Class 0 envelopes. However, our results suggest a relation between the orientation of the magnetic field and the rotational energy, with a larger occurrence of misalignment in sources where strong rotational motions are detected at hundreds to thousands of au scales. We also show that the best agreement between the magnetic field and outflow orientation is found in sources showing no small-scale multiplicity and no large disks at 100 au scales.

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Intracluster Age Gradients In Numerous Young Stellar Clusters

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The pace and pattern of star formation leading to rich young stellar clusters is quite uncertain. In this context, we analyze the spatial distribution of ages within 19 young (median $t < 3$ Myr on the Siess et al. (2000) timescale), morphologically simple, isolated, and relatively rich stellar clusters. Our analysis is based on young stellar object samples from the MYStIX and SFiNCs surveys, and a new estimator of pre-main sequence (PMS) stellar ages, AgeJX, derived from X-ray and near-infrared photometric data. Median cluster ages are computed within four annular subregions of the clusters. We confirm and extend the earlier result of Getman et al. (2014): 80% percent of the clusters show age trends where stars in cluster cores are younger than in outer regions. Our cluster stacking analyses establish the existence of an age gradient to high statistical significance in several ways. Time scales vary with the choice of PMS evolutionary model; the inferred median age gradient across the studied clusters ranges from 0.75 Myr/pc to 1.5 Myr/pc. The empirical finding reported in the present study – late or continuing formation of stars in the cores of star clusters with older stars dispersed in the outer regions – has a strong foundation with other observational studies and with the astrophysical models like the global hierarchical collapse model of Vazquez-Semadeni et al. (2017).

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Young Star Clusters In Nearby Molecular Clouds

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The SFiNCs (Star Formation in Nearby Clouds) project is an X-ray/infrared study of the young stellar populations in 22 star forming regions with distances ≤ 1 kpc designed to extend our earlier MYStIX survey of more distant clusters. Our central goal is to give empirical constraints on cluster formation mechanisms. Using parametric mixture models applied homogeneously to the catalog of SFiNCs young stars, we identify 52 SFiNCs clusters and 19 unclustered stellar structures. The procedure gives cluster properties including location, population, morphology, association to molecular clouds, absorption, age (AgeJX), and infrared spectral energy distribution (SED) slope. Absorption, SED slope, and AgeJX are age indicators. SFiNCs clusters are examined individually, and collectively with MYStIX clusters, to give the following results. (1) SFiNCs is dominated by smaller, younger, and more heavily obscured clusters than MYStIX. (2) SFiNCs cloud-associated clusters have the high ellipticities aligned with their host molecular filaments indicating morphology inherited from their parental clouds. (3) The effect of cluster expansion is evident from the radius-age, radius-absorption, and radius-SED correlations. Core radii increase dramatically from ~ 0.08 to ~ 0.9 pc over the age range 1–3.5 Myr. Inferred gas removal timescales are longer than 1 Myr. (4) Rich, spatially distributed stellar populations are present in SFiNCs clouds representing early generations of star formation. An Appendix compares the performance of the mixture models and nonparametric Minimum Spanning Tree to identify clusters. This work is a foundation for future SFiNCs/MYStIX studies including disk longevity, age gradients, and dynamical modeling.

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Resolving the polarized dust emission of the disk around the massive star powering the HH 80-81 radio jet

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Here we present deep (16 μJy beam^{-1}), very high (40 mas) angular resolution 1.14 mm, polarimetric, Atacama Large Millimeter/submillimeter Array (ALMA) observations towards the massive protostar driving the HH 80-81 radio jet. The observations clearly resolve the disk oriented perpendicular to the radio jet, with a radius of $\simeq 0.17''$ ($\sim$291 au at 1.7 kpc distance). The continuum brightness temperature, the intensity profile, and the polarization properties clearly indicate that the disk is optically thick for a radius of $R \leq 170$ au. The linear polarization of the dust emission is detected almost all along the disk and its properties suggest that dust polarization is produced mainly by self-scattering. However, the polarization pattern presents a clear differentiation between the inner (optically thick) part of the disk and the outer (optically thin) region of the disk, with a sharp transition that occurs at a radius of $\sim 0.1''$ ($\sim$170 au). The polarization characteristics of the inner disk suggest that dust settling has not occurred yet with a maximum dust grain size between 50 and 500 μm. The outer part of the disk has a clear azimuthal pattern but with a significantly higher polarization fraction compared to the inner disk. This pattern is broadly consistent with self-scattering of a radiation field that is beamed radially outward, as expected in the optically thin outer region, although contribution from non-spherical grains aligned with respect to the radiative flux cannot be excluded.

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Chemistry of the High-Mass Protostellar Molecular Clump IRAS 16562-3959

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We present molecular line observations of the high-mass molecular clump IRAS 16562−3959 taken at 3 mm using the Atacama Large Millimeter/submillimeter Array (ALMA) at 1.″7 angular resolution (0.014 pc spatial resolution). This clump hosts the actively accreting high-mass young stellar object (HMYSO) G345.4938+01.4677, associated with a hypercompact HII region. We identify and analyze emission lines from 22 molecular species (encompassing 34 isomers) and classify them into two groups, depending on their spatial distribution within the clump. One of these groups gathers shock tracers (e.g., SiO, SO, HNCO) and species formed in dust grains like methanol (CH_3OH), ethenone or ketene (H_2CCO), and acetaldehyde (CH_3CHO). The second group collects species resembling the dust continuum emission morphology and which are formed mainly in the gas-phase, like hydrocarbons (CCH, c-C_3H_2, CH_3CCH), cyanopolyynes (HC_3N and HC_5N) and cyanides (HCN and CH_3C_3N). Emission from complex organic molecules (COMs) like CH_3OH, propanenitrile (CH_3CH_2CN), and methoxymethane (CH_3OCH_3) arise from gas in the vicinity of a hot molecular core ($T \geq 100$ K) associated with the HMYSO. Other COMs such as propyne (CH_3CCH), acrylonitrile (CH_2CHCN), and acetaldehyde seem to better trace warm ($T \leq 80$ K) dense gas. In addition, deuterated ammonia (NH_2D) is detected mostly in the outskirts of IRAS 16562−3959, associated with near-infrared dark globules, probably gaseous remnants of the clump's prestellar phase. The spatial distribution of molecules in IRAS 16562−3959 supports the view that in protostellar clumps, chemical tracers associated with different evolutionary stages — starless to hot cores/HII regions — exist coevally.

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Chemical survey toward young stellar objects in the Perseus molecular cloud complex

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Chemical diversity of the gas in low-mass protostellar cores is now widely recognized. In order to explore its origin, a survey of chemical composition toward 36 Class 0 and Class I protostars in the Perseus molecular cloud complex, which are selected in an unbiased way under certain physical conditions, has been conducted with the IRAM 30 m

telescope (1.3 mm band) and the NRO 45 m telescope (3 mm band). Multiple lines of C_2H, c-C_3H_2 and CH_3OH have been observed to characterize the chemical composition averaged over a 1000 au scale around the protostar: C_2H and c-C_3H_2 are observed as a proxy of carbon-chain molecules, while CH_3OH is employed as a proxy of complex organic molecules. The beam-averaged column densities derived for these molecules show significant chemical diversity among the sources, where the column density ratios of C_2H/CH_3OH are spread out by 2 orders of magnitude. According to previous studies, the hot corino sources have abundant CH_3OH but deficient C_2H, their C_2H/CH_3OH column density ratios being relatively low. In contrast, the warm-carbon-chain chemistry (WCCC) sources are found to reveal the high C_2H/CH_3OH column density ratios. We find that the majority of the sources observed in this study have intermediate characters between these two distinct chemistry types. A possible trend is seen between the C_2H/CH_3OH ratio and the distance of the source from the edge of a molecular cloud. The sources located near cloud edges or in isolated clouds tend to have a high C_2H/CH_3OH ratio. On the other hand, the sources having a low C_2H/CH_3OH ratio tend to be located in inner regions of the molecular cloud complex. This result gives an important clue to an understanding of the origin of the chemical diversity of protostellar cores in terms of environmental effects.

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Modelling the molecular composition and nuclear-spin chemistry of collapsing prestellar sources

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We study the gravitational collapse of prestellar sources and the associated evolution of their chemical composition. We use the *University of Grenoble Alpes Astrochemical Network* (UGAN), which includes reactions involving the different nuclear–spin states of H_2, H_3^+, and of the hydrides of carbon, nitrogen, oxygen, and sulfur, for reactions involving up to seven protons. In addition, species-to-species rate coefficients are provided for the ortho/para interconversion of the H_3^+ + H_2 system and isotopic variants. The composition of the medium is followed from an initial steady state through the early phase of isothermal gravitational collapse. Both the freeze–out of the molecules on to grains and the coagulation of the grains were incorporated in the model. The predicted abundances and column densities of the spin isomers of ammonia and its deuterated forms are compared with those measured recently towards the prestellar cores H-MM1, L16293E, and Barnard B1. We find that gas–phase processes alone account satisfactorily for the observations, without recourse to grain-surface reactions. In particular, our model reproduces both the isotopologue abundance ratios and the ortho:para ratios of NH_2D and NHD_2 within observational uncertainties. More accurate observations are necessary to distinguish between full scrambling processes—as assumed in our gas-phase network—and direct nucleus- or atom-exchange reactions.

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Mid-infrared Multi-wavelength Imaging of Ophiuchus IRS 48 Transitional Disk

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Transitional disks around the Herbig Ae/Be stars are fascinating targets in the contexts of disk evolution and also planet formation. Oph IRS 48 is one of such Herbig Ae stars, which shows an inner dust cavity and azimuthally lopsided large dust distribution. We present new images of Oph IRS 48 at eight mid-infrared (MIR) wavelengths from 8.59 to 24.6 μm taken with the COMICS mounted on the 8.2 m Subaru Telescope. The N-band (7 to 13 μm) images show that the flux distribution is centrally peaked with a slight spatial extent, while the Q-band (17 to 25 μm) images show asymmetric double peaks (east and west). Using 18.8 and 24.6 μm images, we derived the dust temperature at both east and west peaks to be 135±22 K. Thus, the asymmetry may not be attributed to a difference in the temperature. Comparing our results with previous modeling works, we conclude that the inner disk is aligned to the outer disk. A shadow casted by the optically thick inner disk has a great influence on the morphology of MIR thermal emission from the outer disk.

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Blinded by the light: on the relationship between CO first overtone emission and mass accretion rate in massive young stellar objects

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To date, there is no explanation as to why disc-tracing CO first overtone (or 'bandhead') emission is not a ubiquitous feature in low- to medium-resolution spectra of massive young stellar objects, but instead is only detected toward approximately 25 per cent of their spectra. In this paper, we investigate the hypothesis that only certain mass accretion rates result in detectable bandhead emission in the near infrared spectra of MYSOs. Using an analytic disc model combined with an LTE model of the CO emission, we find that high accretion rates ($\gtrsim 10^{-4}\,M_{\odot}yr^{-1}$) result in large dust sublimation radii, a larger contribution to the K-band continuum from hot dust at the dust sublimation radius, and therefore correspondingly lower CO emission with respect to the continuum. On the other hand, low accretion rates ($\lesssim 10^{-6}\,M_{\odot}yr^{-1}$) result in smaller dust sublimation radii, a correspondingly smaller emitting area of CO, and thus also lower CO emission with respect to the continuum. In general, moderate accretion rates produce the most prominent, and therefore detectable, CO first overtone emission. We compare our findings to a recent near-infrared spectroscopic survey of MYSOs, finding results consistent with our hypothesis. We conclude that the detection rate of CO bandhead emission in the spectra of MYSOs could be the result of MYSOs exhibiting a range of mass accretion rates, perhaps due to the variable accretion suggested by recent multi-epoch observations of these objects.

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Signatures of Young Planets in the Continuum Emission From Protostellar Disks

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Many protostellar disks show central cavities, rings, or spiral arms likely caused by low-mass stellar or planetary companions, yet few such features are conclusively tied to bodies embedded in the disks. We note that even small features on the disks surface cast shadows, because the starlight grazes the surface. We therefore focus on accurately

computing the disks thickness, which depends on its temperature. We present models with temperatures set by the balance between starlight heating and radiative cooling, that are also in vertical hydrostatic equilibrium. The planet has 20, 100, or 1000 Earth masses, ranging from barely enough to perturb the disk significantly, to clearing a deep tidal gap. The hydrostatic balance strikingly alters the model disks appearance. The planet-carved gaps outer wall puffs up under starlight heating, throwing a shadow across the disk beyond. The shadow appears in scattered light as a dark ring that could be mistaken for a gap opened by another more distant planet. The surface brightness contrast between outer wall and shadow for the 1000-Earth-mass planet is an order of magnitude greater than a model neglecting the temperature disturbances. The shadow is so deep it largely hides the planet-launched spiral waves outer arm. Temperature gradients are such that outer low-mass planets undergoing orbital migration will converge within the shadow. Furthermore the temperature perturbations affect the shape, size, and contrast of features at millimeter and centimeter wavelengths. Thus radiative heating and cooling are key to the appearance of protostellar disks with embedded planets.

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Radiative transfer modelling of W33A MM1: 3-D structure and dynamics of a complex massive star forming region

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We present a composite model and radiative transfer simulations of the massive star forming core W33A MM1. The model was tailored to reproduce the complex features observed with ALMA at $\sim$0.″2 resolution in CH_3CN and dust emission. The MM1 core is fragmented into six compact sources coexisting within $\sim$1000 au. In our models, three of these compact sources are better represented as disc-envelope systems around a central (proto)star, two as envelopes with a central object, and one as a pure envelope. The model of the most prominent object (Main) contains the most massive (proto)star ($M_\star \sim 7\ M_\odot$) and disc+envelope ($M_{\rm gas} \sim 0.4\ M_\odot$), and is the most luminous ($L_{\rm Main} \sim 10^4$ $L_\odot$). The model discs are small (a few hundred au) for all sources. The composite model shows that the elongated spiral-like feature converging to the MM1 core can be convincingly interpreted as a filamentary accretion flow that feeds the rising stellar system. The kinematics of this filament is reproduced by a parabolic trajectory with focus at the center of mass of the region. Radial collapse and fragmentation within this filament, as well as smaller filamentary flows between pairs of sources are proposed to exist. Our modelling supports an interpretation where what was once considered as a single massive star with a $\sim$$10^3$ au disc and envelope, is instead a forming stellar association which appears to be virialized and to form several low-mass stars per high-mass object.

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Diagnostic value of far-IR water ice features in T Tauri disks

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This paper investigates how the far-IR water ice features can be used to infer properties of disks around T Tauri stars and the water ice thermal history. We explore the power of future observations with SOFIA/HIRMES and SPICA's proposed far-IR instrument SAFARI. A series of detailed radiative transfer disk models around a representative T Tauri star are used to investigate how the far-IR water ice features at 45 and 63 μm change with key disk properties: disk size, grain sizes, disk dust mass, dust settling, and ice thickness. In addition, a series of models is devised to calculate the water ice emission features from warmup, direct deposit and cool down scenarios of the water ice in disks. Photodesorption from icy grains in disk surfaces weakens the mid-IR water ice features by factors 4–5. The far-IR water ice emission features originate from small grains at the surface snow line in disks at distance of 10–100 au. Unless this reservoir is missing in disks (e.g., transitional disks with large cavities), the feature strength is not changing. Grains larger than 10 μm do not contribute to the features. Grain settling (using turbulent description) is affecting the strength of the ice features by at most 15%. The strength of the ice feature scales with the disk dust mass and water ice fraction on the grains, but saturates for dust masses larger than 10^{-4} $M_\odot$ and for ice mantles that increase the dust mass by more than 50%. The various thermal histories of water ice leave an imprint on the shape of the features (crystalline/amorphous) as well as on the peak strength and position of the 45 μm feature. SOFIA/HIRMES can only detect crystalline ice features much stronger than simulated in our standard T Tauri disk model in deep exposures (1 hr). SPICA/SAFARI can detect the typical ice features in our standard T Tauri disk model in short exposures (10 min).

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A 100 au-Wide Bipolar Rotating Shell Emanating From the HH 212 Protostellar Disk: A Disk Wind?

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HH 212 is a Class 0 protostellar system found to host a "hamburger"-shaped dusty disk with a rotating disk atmosphere and a collimated SiO jet at a distance of ∼400 pc. Recently, a compact rotating outflow has been detected in SO and SO_2 toward the center along the jet axis at ∼52 au (0.″13) resolution. Here we resolve the compact outflow into a small-scale wide-opening rotating outflow shell and a collimated jet, with the observations in the same S-bearing molecules at ∼16 au (0.″04) resolution. The collimated jet is aligned with the SiO jet, tracing the shock interactions in the jet. The wide-opening outflow shell is seen extending out from the inner disk around the SiO jet and has a width of ∼100 au. It is not only expanding away from the center, but also rotating around the jet axis. The specific angular momentum of the outflow shell is ∼40 au km s^{-1}. Simple modeling of the observed kinematics suggests that the rotating outflow shell can trace either a disk wind or disk material pushed away by an unseen wind from the inner disk or protostar. We also resolve the disk atmosphere in the same S-bearing molecules, confirming the Keplerian rotation there.

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A holistic perspective on the dynamics of G035.39-00.33: the interplay between gas and magnetic fields

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Magnetic field is one of the key agents that play a crucial role in shaping molecular clouds and regulating star formation, yet the complete information on the magnetic field is not well constrained due to the limitations in observations. We study the magnetic field in the massive infrared dark cloud G035.39-00.33 from dust continuum polarization observations at 850 μm with SCUBA-2/POL-2 at JCMT. The magnetic field tends to be perpendicular to the densest part of the main filament (F_M), whereas it has a less defined relative orientation in the rest of the structure, where it tends to be parallel to some diffuse regions. A mean plane-of-the-sky magnetic field strength of $\sim$50 μG for F_M is obtained using Davis-Chandrasekhar-Fermi method. Based on ^{13}CO (1-0) line observations, we suggest a formation scenario of F_M due to large-scale ($\sim$10 pc) cloud-cloud collision. Using additional NH_3 line data, we estimate that F_M will be gravitationally unstable if it is only supported by thermal pressure and turbulence. The northern part of F_M, however, can be stabilized by a modest additional support from the local magnetic field. The middle and southern parts of F_M are likely unstable even if the magnetic field support is taken into account. We claim that the clumps in F_M may be supported by turbulence and magnetic fields against gravitational collapse. Finally, we identified for the first time a massive ($\sim$200 $M_\odot$), collapsing starless clump candidate, "c8", in G035.39-00.33. The magnetic field surrounding "c8" is likely pinched, hinting at an accretion flow along the filament.

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A Masing Event in NGC 6334 I: Contemporaneous Flaring of Hydroxyl, Methanol and Water Masers

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As a product of the maser monitoring program with the 26 m telescope of the Hartebeesthoek Radio Astronomy Observatory (HartRAO), we present an unprecedented, contemporaneous flaring event of 10 maser transitions in hydroxyl, methanol, and water that began in 2015 January in the massive star-forming region NGC 6334 I in the velocity range −10 to −2 km/s. The 6.7 GHz methanol and 22.2 GHz water masers began flaring within 22 days of each other, while the 12.2 GHz methanol and 1665 MHz hydroxyl masers flared 80 and 113 days later respectively. The 1665 MHz, 6.7 GHz, and 22.2 GHz masers have all remained in their flared state for nearly 3 years. The brightest flaring components increased by factors of 66, 21, 26, and 20 in the 12.2 and 6.7 GHz methanol, 1665 MHz hydroxyl and 22.2 GHz water maser transitions respectively; some weaker components increased by up to a factor of 145. We also report new maser emission in the 1720, 6031, and 6035 MHz OH lines and the 23.1 GHz methanol line, along with the detection of only the fifth 4660 MHz OH maser. We note the correlation of this event with the extraordinary (sub)millimeter continuum outburst from the massive protostellar system NGC 6334 I-MM1 and discuss the implications of the observed time lags between different maser velocity components on the nature of the outburst. Finally, we identify two earlier epoch maser flaring events likely associated with this object, which suggest a recurring accretive phenomenon that generates powerful radiative outbursts.

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An Empirical Planetesimal Belt Radius - Stellar Luminosity Relation

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Resolved observations of millimetre-sized dust, tracing larger planetesimals, have pinpointed the location of 26 Edgeworth-Kuiper belt analogs. We report that a belt's distance R to its host star correlates with the star's luminosity $L_\star$, following $R \propto {L_\star}^{0.19}$ with a low intrinsic scatter of ∼17%. Remarkably, our Edgeworth-Kuiper belt in the Solar System and the two CO snow lines imaged in protoplanetary disks lie close to this R–$L_\star$ relation, suggestive of an intrinsic relationship between protoplanetary disk structures and belt locations. To test the effect of bias on the relation, we use a Monte Carlo approach and simulate uncorrelated model populations of belts. We find that observational bias could produce the slope and intercept of the R–$L_\star$ relation, but is unable to reproduce its low scatter. We then repeat the simulation taking into account the collisional evolution of belts, following the steady state model that fits the belt population as observed through infrared excesses. This significantly improves the fit by lowering the scatter of the simulated R–$L_\star$ relation; however, this scatter remains only marginally consistent with the one observed. The inability of observational bias and collisional evolution alone to reproduce the tight relationship between belt radius and stellar luminosity could indicate that planetesimal belts form at preferential locations within protoplanetary disks. The similar trend for CO snow line locations would then indicate that the formation of planetesimals and/or planets in the outer regions of planetary systems is linked to the volatility of their building blocks, as postulated by planet formation models.

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Herschel PACS observations of 4-10 Myr old Classical T Tauri stars in Orion OB1

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We present *Herschel* PACS observations of 8 Classical T Tauri Stars in the $\sim 7-10$ Myr old OB1a and the $\sim 4-5$ Myr old OB1b Orion sub-asscociations. Detailed modeling of the broadband spectral energy distributions, particularly the strong silicate emission at 10 μm, shows that these objects are (pre)transitional disks with some amount of small optically thin dust inside their cavities, ranging from $\sim$ 4 AU to $\sim$ 90 AU in size. We analyzed *Spitzer* IRS spectra for two objects in the sample: CVSO-107 and CVSO-109. The IRS spectrum of CVSO-107 indicates the presence of crystalline material inside its gap while the silicate feature of CVSO-109 is characterized by a pristine profile produced by amorphous silicates; the mechanisms creating the optically thin dust seem to depend on disk local conditions.

Using millimeter photometry we estimated dust disk masses for CVSO-107 and CVSO-109 lower than the minimum mass of solids needed to form the planets in our Solar System, which suggests that giant planet formation should be over in these disks. We speculate that the presence and maintenance of optically thick material in the inner regions of these pre-transitional disks might point to low-mass planet formation.

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Inside-Out Planet Formation. V. Structure of the Inner Disk as Implied by the MRI

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The ubiquity of Earth to super-Earth sized planets found very close to their host stars has motivated *in situ* formation models. In particular, Inside-Out Planet Formation is a scenario in which planets coalesce sequentially in the disk, at the local gas pressure maximum near the inner boundary of the dead zone. The pressure maximum arises from a decline in viscosity, going from the active innermost disk (where thermal ionization yields high viscosities via the magneto-rotational instability (MRI)) to the adjacent dead zone (where the MRI is quenched). Previous studies of the pressure maximum, based on α-disk models, have assumed ad hoc values for the viscosity parameter α in the active zone, ignoring the detailed MRI physics. Here we explicitly couple the MRI criteria to the α-disk equations, to find steady-state solutions for the disk structure. We consider both Ohmic and ambipolar resistivities, and a range of disk accretion rates (10^{-10}–$10^{-8}\,\mathrm{M_\odot\,yr^{-1}}$), stellar masses ($0.1$–$1\,\mathrm{M_\odot}$), and fiducial values of the *non*-MRI α-viscosity in the dead zone ($\alpha_{\rm DZ} = 10^{-5}$–$10^{-3}$). We find that: *(1)* A midplane pressure maximum forms radially *outside* the dead zone inner boundary; *(2)* Hall resistivity dominates near the inner disk midplane, perhaps explaining why close-in planets do *not* form in $\sim$50% of systems; *(3)* X-ray ionization can compete with thermal ionization in the inner disk, because of the low steady-state surface density there; and *(4)* our inner disks are viscously unstable to surface density perturbations.

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C^+ distribution around S 1 in ρ Ophiuchi

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We analyze a [C II] 158 μm map obtained with the L2 GREAT receiver on SOFIA of the emission/reflection nebula illuminated by the early B star S 1 in the ρ Oph A cloud core. This data set has been complemented with maps of CO(3–2), ^{13}CO(3–2) and C^{18}O(3-2), observed as a part of the JCMT Gould Belt Survey, with archival HCO$^+$(4–3) JCMT data, as well as with [O I] 63 and 145 μm imaging with *Herschel*/PACS. The [C II] emission is completely dominated by the strong PDR emission from the nebula surrounding S 1 expanding into the dense Oph A molecular cloud west and south of S 1. The [C II] emission is significantly blue shifted relative to the CO spectra and also relative to the systemic velocity, particularly in the northwestern part of the nebula. The [C II] lines are broader towards the center of the S 1 nebula and narrower towards the PDR shell. The [C II] lines are strongly self-absorbed over an extended region in the S 1 PDR. Based on the strength of the [^{13}C II] F = 2–1 hyperfine component, [C II] is significantly optically thick over most of the nebula. CO and ^{13}CO(3–2) spectra are strongly self-absorbed, while C^{18}O(3–2) is single peaked and centered in the middle of the self-absorption. We have used a simple two-layer LTE model to characterize the background and foreground cloud contributing to the [C II] emission. From this analysis we estimate the extinction due to the foreground cloud to be ~ 9.9 mag, which is slightly less than the reddening estimated towards S 1. Since some of the hot gas in the PDR is not traced by low J CO emission, this result appears quite plausible. Using a plane parallel PDR model with the observed [O I](145)/[C II] brightness ratio and an estimated FUV intensity of 3100–5000 G$_0$ suggests that the density of the [C II] emitting gas is $\sim 3-4\times10^3\,\mathrm{cm^{-3}}$.

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The unexpectedly large proportion of high-mass star-forming cores in a Galactic mini-starburst

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Understanding the processes that determine the stellar Initial Mass Function (IMF) is a critical unsolved problem, with profound implications for many areas of astrophysics. In molecular clouds, stars are formed in cores, gas condensations which are sufficiently dense that gravitational collapse converts a large fraction of their mass into a star or small clutch of stars. In nearby star-formation regions, the core mass function (CMF) is strikingly similar to the IMF, suggesting that the shape of the IMF may simply be inherited from the CMF. Here we present 1.3 mm observations, obtained with ALMA, the world's largest interferometer, of the active star-formation region W43-MM1, which may be more representative of the Galactic-disk regions where most stars form. The unprecedented resolution of these observations reveals, for the first time, a statistically robust CMF at high masses, with a slope that is markedly shallower than the IMF. This seriously challenges our understanding of the origin of the IMF.

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Layers in the Central Orion Nebula

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The existence of multiple layers in the inner Orion Nebula has been revealed using data from an Atlas of spectra at 2" and 12 km s^{-1} resolution. These data were sometimes grouped over Samples of 10" ×10" to produce high Signal to Noise spectra and sometimes grouped into sequences of pseudo-slit Spectra of 12.8" – 39" width for high spatial resolution studies. Multiple velocity systems were found: V_{MIF} traces the Main Ionization Front (MIF), V_{scat} arises from back-scattering of V_{MIF} emission by particles in the background Photon Dissociation Region (PDR), V_{low} is an ionized layer in front of the MIF and if it is the source of the stellar absorption lines seen in the Trapezium stars, it must lie between the foreground Veil and those stars, $V_{new,[O\ III]}$ may represent ionized gas evaporating from the Veil away from the observer. There are features such as the Bright Bar where variations of velocities are due to changing tilts of the MIF, but velocity changes above about 25" arise from variations in velocity of the background PDR. In a region 25" ENE of the Orion-S Cloud one finds dramatic changes in the [O III] components, including the signals from the $V_{low,[O\ III]}$ and $V_{MIF,[O\ III]}$ becoming equal, indicating shadowing of gas from stellar photons of greater than 24.6 eV. This feature is also seen in areas to the west and south of the Orion-S Cloud.

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Formation of close-in super-Earths in evolving protoplanetary disks due to disk winds

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Planets with masses larger than about 0.1 Earth-masses undergo rapid inward migration (type I migration) in a standard protoplanetary disk. Recent magnetohydrodynamical simulations revealed the presence of magnetically driven disk winds, which would alter the disk profile and the type I migration in the close-in region. We investigate orbital evolution of planetary embryos in disks that viscously evolve under the effects of disk winds. The aim is to discuss effects of altered disk profiles on type I migration. In addition, we aim to examine whether observed distributions of close-in super-Earths can be reproduced by simulations that include effects of disk winds. We perform N-body simulations of super-Earth formation from planetary embryos, in which a recent model for disk evolution is used. We explore a wide range of parameters and draw general trends. We also carry out N-body simulations of close-in super-Earth formation from embryos in such disks under various conditions. We find that the type I migration is significantly suppressed in many cases. Even in cases in which inward migration occurs, the migration timescale is lengthened to 1 Myr, which mitigates the type I migration problem. This is because the gas surface density is decreased and has a flatter profile in the close-in region due to disk winds. We find that when the type I migration is significantly suppressed, planets undergo late orbital instability during the gas depletion, leading to a non-resonant configuration. We also find that observed distributions of close-in super-Earths (e.g., period ratio, mass ratio) can be reproduced. In addition, we show that in some results of simulations, systems with a chain of resonant planets, like the TRAPPIST-1 system, form.

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Formation of the terrestrial planets in the solar system around 1 au via radial concentration of planetesimals

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No planets exist inside the orbit of Mercury and the terrestrial planets of the solar system exhibit a localized configuration. According to thermal structure calculation of protoplanetary disks, a silicate condensation line ($\sim$1300 K) is located around 0.1 au from the Sun except for the early phase of disk evolution, and planetesimals could have formed inside the orbit of Mercury. A recent study of disk evolution that includes magnetically driven disk winds showed that the gas disk obtains a positive surface density slope inside $\sim$1 au from the central star. In a region with positive midplane pressure gradient, planetesimals undergo outward radial drift. We investigate the radial drift of planetesimals and type I migration of planetary embryos in a disk that viscously evolves with magnetically driven disk winds. We show a case in which no planets remain in the close-in region. Radial drifts of planetesimals are simulated using a recent disk evolution model that includes effects of disk winds. The late stage of planet formation is also examined by performing N-body simulations of planetary embryos. We demonstrate that in the middle stage of disk evolution, planetesimals can undergo convergent radial drift in a magnetorotational instability (MRI)-inactive disk, in which the pressure maximum is created, and accumulate in a narrow ring-like region with an inner edge at $\sim$0.7 au from the Sun. We also show that planetary embryos that may grow from the narrow planetesimal ring do not exhibit significant type I migration in the late stage of disk evolution. The origin of the localized configuration of the terrestrial planets of the solar system, in particular the deficit of close-in planets, can be explained by the convergent radial drift of planetesimals in disks with a positive pressure gradient in the close-in region.

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High-resolution near-IR Spectral mapping with H_2 and [Fe II] lines of Multiple Outflows around LkHα 234

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We present a high-resolution, near-IR spectroscopic study of multiple outflows in the LkHα 234 star formation region using the Immersion GRating INfrared Spectrometer (IGRINS). Spectral mapping over the blueshifted emission of HH 167 allowed us to distinguish at least three separate, spatially overlapped, outflows in H_2 and [Fe II] emission. We show that the H_2 emission represents not a single jet, but complex multiple outflows driven by three known embedded sources: MM1, VLA 2, and VLA 3. There is a redshifted H_2 outflow at a low velocity, $V_{\rm LSR} < +50$ km s^{-1}, with respect to the systemic velocity of $V_{\rm LSR} = -11.5$ km s^{-1}, that coincides with the H_2O masers seen in earlier radio observations two arcseconds southwest of VLA 2. We found that the previously detected FeII jet with $|V_{\rm LSR}| > 100$ km s^{-1} driven by VLA 3B is also detected in H_2 emission, and confirm that this jet has a position angle about 240°. Spectra of the redshifted knots at $14''-65''$ northeast of LkHα 234 are presented for the first time. These spectra also provide clues to the existence of multiple outflows. We detected high-velocity ($50-120$ km s^{-1}) H_2 gas in the multiple outflows around LkHα 234. Since these gases move at speeds well over the dissociation velocity (> 40 km s^{-1}), the emission must originate from the jet itself rather than H_2 gas in the ambient medium. Also, position-velocity diagrams and excitation diagram indicate that emission from knot C in HH 167 come from two different phenomena, shocks and photodissociation.

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New places and phases of CO-poor/CI-rich molecular gas in the Universe

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In this work we extend the work on the recently discovered role of Cosmic Rays (CRs) in regulating the average CO/H_2 abundance ratio in molecular clouds (and thus their CO line visibility) in starburst galaxies, and find that it can lead to a CO-poor/CI-rich H_2 gas phase even in environments with Galactic or in only modestly enhanced CR backgrounds expected in ordinary star-forming galaxies. Furthermore, the same CR-driven astro-chemistry raises the possibility of a widespread phase transition of molecular gas towards a CO-poor/CI-rich phase in: a) molecular gas outflows

found in star-forming galaxies, b) active galactic nuclei (AGNs), and c) near synchrotron-emitting radio jets and the radio-loud cores of powerful radio galaxies. For main sequence galaxies we find that CRs can render some of their molecular gas mass CO-invisible, compounding the effects of low metallicities. Imaging the two fine structure lines of atomic carbon with resolution high enough to search beyond the CI/CO-bright line regions associated with central starbursts can reveal such a CO-poor/CI-rich molecular gas phase, provided that relative brightness sensitivity levels of $T_b(\text{C I } 1-0)/T_b(\text{CO } J=1-0)\sim 0.15$ are reached. The capability to search for such gas in the Galaxy is now at hand with the new high-frequency survey telescope HEAT deployed in Antarctica and future ones to be deployed in Dome A. ALMA can search for such gas in star-forming spiral disks, galactic molecular gas outflows and the CR-intense galactic and circumgalactic gas-rich environments of radio-loud objects.

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Distribution of Serpens South protostars revealed with ALMA

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Aims. We investigated the masses and spatial distributions of pre-stellar and protostellar candidates in the young, low-mass star forming region Serpens South, where active star formation is known to occur along a predominant filamentary structure. Previous observations used to study these distributions have been limited by two important observational factors: (1) sensitivity limits that leave the lowest-mass sources undetected, or (2) resolution limits that cannot distinguish binaries and/or cluster members in close proximity.
Methods. Recent millimeter-wavelength interferometry observations can now uncover faint and/or compact sources in order to study a more complete population of protostars, especially in nearby ($D < 500$ pc) clusters. Here we present ALMA observations of 1 mm (Band 6) continuum in a $3' \times 2'$ region at the center of Serpens South. Our angular resolution of $\sim 1''$ is equivalent to $\sim$400 au, corresponding to scales of envelopes and/or disks of protostellar sources.
Results. We detect 52 sources with 1 mm continuum, and we measure masses of 0.002–0.9 $M_\odot$ corresponding to gas and dust in the disk and/or envelope of the protostellar system. For the deeply embedded (youngest) sources with no IR counterparts, we find evidence of mass segregation and clustering according to: the Minimum Spanning Tree method, distribution of projected separations between unique sources, and concentration of higher-mass sources near to the dense gas at the cluster center.
Conclusions. The mass segregation of the mm sources is likely primordial rather than dynamical given the young age of this cluster, compared with segregation time. This is the first case to show this for mm sources in a low-mass protostellar cluster environment.

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Circumstellar Disk Lifetimes In Numerous Galactic Young Stellar Clusters

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Photometric detections of dust circumstellar disks around pre-main sequence (PMS) stars, coupled with estimates of stellar ages, provide constraints on the time available for planet formation. Most previous studies on disk longevity, starting with Haisch, Lada & Lada (2001), use star samples from PMS clusters but do not consider datasets with homogeneous photometric sensitivities and/or ages placed on a uniform timescale. Here we conduct the largest study to date of the longevity of inner dust disks using X-ray and 1–8 micrometre infrared photometry from the MYStIX and SFiNCs projects for 69 young clusters in 32 nearby star-forming regions with ages $t \leq 5$ Myr. Cluster ages are derived by combining the empirical AgeJX method with PMS evolutionary models, which treat dynamo-generated magnetic fields in different ways. Leveraging X-ray data to identify disk-free objects, we impose similar stellar mass sensitivity limits for disk-bearing and disk-free YSOs while extending the analysis to stellar masses as low as $M \sim 0.1$ $M_\odot$. We find that the disk longevity estimates are strongly affected by the choice of PMS evolutionary model. Assuming a disk fraction of 100% at zero age, the inferred disk half-life changes significantly, from $t_{1/2} \sim 1.3-2$ Myr to $t_{1/2} \sim 3.5$ Myr when switching from non-magnetic to magnetic PMS models. In addition, we find no statistically significant evidence that disk fraction varies with stellar mass within the first few Myr of life for stars with masses < 2 $M_\odot$, but our samples may not be complete for more massive stars. The effects of initial disk fraction and star-forming environment are also explored.

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Multiple Stellar Fly-Bys Sculpting the Circumstellar Architecture in RW Aurigae

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We present high-resolution ALMA Band 6 and 7 observations of the tidally disrupted protoplanetary disks of the RW Aurigae binary. Our observations reveal the presence of additional tidal streams to the previously observed tidal arm around RW Aur A. The observed configuration of tidal streams surrounding RW Aur A and B is incompatible with a single star-disk tidal encounter, suggesting that the RW Aurigae system has undergone multiple fly-by interactions. We also resolve the circumstellar disks around RW Aur A and B, with CO radii of 68 au and 38 au consistent with tidal truncation, and 2.5 times smaller dust emission radii. The disks appear misaligned by 12° or 57°. Using new photometric observations from the American Association of Variable Star Observers (AAVSO) and All Sky Automated Survey for SuperNovae (ASAS-SN) archives, we have also identified an additional dimming event of the primary that began in late 2017 and is currently ongoing. With over a century of photometric observations, we are beginning to explore the same spatial scales as ALMA.

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http://arxiv.org/pdf/1804.09190

A Cavity of Large Grains in the Disk Around the Group II Herbig Ae/Be Star HD 142666

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Herbig Ae/Be (HAeBe) stars have been classified into Group I or Group II, which were initially thought to be flared and flat disks, respectively. Several Group I sources have been shown to have large gaps, suggesting ongoing planet formation, while no large gaps have been found in the disks of Group II sources. We analyzed the disk around the Group II source, HD 142666, using irradiated accretion disk modeling of the broad-band spectral energy distribution along with the 1.3 millimeter spatial brightness distribution traced by Atacama Large Millimeter and Submillimeter Array (ALMA) observations. Our model reproduces the available data, predicting a high degree of dust settling in the disk, which is consistent with the Group II classification of HD 142666. In addition, the observed visibilities and synthesized image could only be reproduced when including a depletion of large grains out to ∼16 au in our disk model, although the ALMA observations did not have enough angular resolution to fully resolve the inner parts of the disk. These results may suggest that some disks around Group II HAeBe stars have cavities of large grains as well. Further ALMA observations of Group II sources are needed to discern how commonly cavities occur in this class of objects, as well as to reveal their possible origins.

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https://arxiv.org/pdf/1804.07343.pdf

Dust Polarization Toward Embedded Protostars in Ophiuchus with ALMA. I. VLA 1623

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We present high resolution (∼ 30 au) ALMA Band 6 dust polarization observations of VLA 1623. The VLA 1623 data resolve compact ∼ 40 au inner disks around the two protobinary sources, VLA 1623-A and VLA 1623-B, and also an extended ∼ 180 au ring of dust around VLA 1623-A. This dust ring was previously identified as a large disk in lower-resolution observations. We detect highly structured dust polarization toward the inner disks and the extended ring with typical polarization fractions ≈ 1.7% and ≈ 2.4%, respectively. The two components also show distinct polarization morphologies. The inner disks have uniform polarization angles aligned with their minor axes. This morphology is consistent with expectations from dust scattering. By contrast, the extended dust ring has an azimuthal polarization morphology not previously seen in lower-resolution observations. We find that our observations are well fit by a static, oblate spheroid model with a flux-frozen, poloidal magnetic field. We propose that the polarization traces magnetic grain alignment likely from flux freezing on large scales and magnetic diffusion on small scales. Alternatively, the azimuthal polarization may be attributed to grain alignment by the anisotropic radiation field. If the grains are radiatively aligned, then our observations indicate that large (∼ 100 μm) dust grains grow quickly at large angular extents. Finally, we identify significant proper motion of VLA 1623 using our observations and those in the literature. This result indicates that the proper motion of nearby systems must be corrected for when combining ALMA data from different epochs.

Accepted by ApJ

https://arxiv.org/pdf/1804.05968

Spitzer Light Curves of the Young, Planetary-Mass TW Hya Members 2MASS J11193254−1137466AB and WISEA J114724.10−204021.3

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We present Spitzer Space Telescope time-series photometry at 3.6 and 4.5 μm of 2MASS J11193254−1137466AB and WISEA J114724.10−204021.3, two planetary-mass, late-type (∼L7) brown dwarf members of the ∼10 Myr old TW Hya Association. These observations were taken in order to investigate whether or not a tentative trend of increasing variability amplitude with decreasing surface gravity seen for L3–L5.5 dwarfs extends to later-L spectral types and to explore the angular momentum evolution of low-mass objects. We examine each light curve for variability and find a rotation period of $19.39^{+0.33}_{-0.28}$ hours and semi-amplitudes of $0.798^{+0.081}_{-0.083}$% at 3.6 μm and $1.108^{+0.093}_{-0.094}$% at 4.5 μm for WISEA J114724.10−204021.3. For 2MASS J11193254−1137466AB, we find a single period of $3.02^{+0.04}_{-0.03}$ hours with semi-amplitudes of $0.230^{+0.036}_{-0.035}$% at 3.6 μm and 0.453±0.037% at 4.5 μm, which we find is possibly due to the rotation of one component of the binary. Combining our results with 12 other late-type L dwarfs observed with Spitzer from the literature, we find no significant differences between the 3.6 μm amplitudes of low surface gravity and field gravity late-type L brown dwarfs at Spitzer wavelengths, and find tentative evidence (75% confidence) of higher amplitude variability at 4.5 μm for young, late-type Ls. We also find a median rotation period of young brown dwarfs (10–300 Myr) of ∼10 hr, more than twice the value of the median rotation period of field age brown dwarfs (∼4 hr), a clear signature of brown dwarf rotational evolution.

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A universal spin-mass relation for brown dwarfs and planets

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While brown dwarfs show similarities with stars in their early life, their spin evolution is much more akin to that of planets. We have used lightcurves from the K2 mission to measure new rotation periods for 18 young brown dwarfs in the Taurus star-forming region. Our sample spans masses from 0.02 to 0.08 $M_\odot$ and has been characterised extensively in the past. To search for periods, we utilize three different methods (autocorrelation, periodogram, Gaussian Processes). The median period for brown dwarfs with disks is twice as long as for those without (3.1 vs. 1.6 d), a signature of rotational braking by the disk, albeit with small numbers. With an overall median period of 1.9 d, brown dwarfs in Taurus rotate slower than their counterparts in somewhat older (3-10 Myr) star-forming regions, consistent with spin-up of the latter due to contraction and angular momentum conservation, a clear sign that disk braking overall is inefficient and/or temporary in this mass domain. We confirm the presence of a linear increase of the typical rotation period as a function of mass in the sub-stellar regime. The rotational velocities, when calculated forward to the age of the solar system assuming angular momentum conservation, fit the known spin-mass relation for solar system planets and extra-solar planetary-mass objects. This spin-mass trend holds over six orders of magnitude in mass, including objects from several different formation paths. Our result implies that brown dwarfs by and large retain their primordial angular momentum through the first few Myr of their evolution.

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https://arxiv.org/pdf/1804.07380

Extended Millimeter Emission in the HD 141569 Circumstellar Disk Detected with ALMA

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We present archival ALMA observations of the HD 141569 circumstellar disk at 345, 230, and 100 GHz. These data detect extended millimeter emission that is exterior to the inner disk. We find through simultaneous visibility modeling of all three data sets that the system's morphology is described well by a two-component disk model. The inner disk ranges from approximately 16 to 45 au with a spectral index of 1.81 ($q = 2.95$) and the outer disk ranges from 95 to 300 au with a spectral index of 2.28 ($q = 3.21$). Azimuthally averaged radial emission profiles derived from the continuum images at each frequency show potential emission that is consistent with the visibility modeling. The analysis presented here shows that at ∼5 Myr HD 141569's grain size distribution is steeper, and therefore more evolved, in the outer disk than in the inner disk.

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http://arxiv.org/pdf/1804.09724

New member candidates of Upper Scorpius from Gaia DR1

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Context. Selecting a cluster in proper motion space is an established method for identifying members of a star forming region. The first data release from Gaia (DR1) provides an extremely large and precise stellar catalogue, which when combined with the Tycho-2 catalogue gives the 2.5 million parallaxes and proper motions contained within the Tycho-Gaia Astrometric Solution (TGAS).
Aims. We aim to identify new member candidates of the nearby Upper Scorpius subgroup of the Scorpius-Centaurus Complex within the TGAS catalogue. In doing so, we also aim to validate the use of the DBSCAN clustering algorithm on spatial and kinematic data as a robust member selection method.
Methods. We constructed a method for member selection using a density-based clustering algorithm (DBSCAN) applied over proper motion and distance. We then applied this method to Upper Scorpius, and evaluated the results and performance of the method.
Results. We identified 167 member candidates of Upper Scorpius, of which 78 are new, distributed within a 10° radius from its core. These member candidates have a mean distance of 145.6±7.5 pc, and a mean proper motion of (−11.4, −23.5)±(0.7, 0.4) mas yr^{-1}. These values are consistent with measured distances and proper motions of previously identified bona-fide members of the Upper Scorpius association.

Accepted by A&A

http://arxiv.org/pdf/1804.10107

Abstracts of recently accepted major reviews

Water Partitioning in Planetary Embryos and Protoplanets with Magma Oceans

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The water content of magma oceans is widely accepted as a key factor that determines whether a terrestrial planet is habitable. Water ocean mass is determined as a result not only of water delivery and loss, but also of water partitioning among several reservoirs. Here we review our current understanding of water partitioning among the atmosphere, magma ocean, and solid mantle of accreting planetary embryos and protoplanets just after giant collisions. Magma oceans are readily formed in planetary embryos and protoplanets in their accretion phase. Significant amounts of water are partitioned into magma oceans, provided the planetary building blocks are water-rich enough. Particularly important but still quite uncertain issues are how much water the planetary building blocks contain initially and how water goes out of the solidifying mantle and is finally degassed to the atmosphere. Constraints from both solar-system explorations and exoplanet observations and also from laboratory experiments are needed to resolve these issues.

Accepted by Space Science Reviews

http://arxiv.org/pdf/1804.09294

Connecting Planetary Composition with Formation

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The rapid advances in observations of the different populations of exoplanets, the characterization of their host stars and the links to the properties of their planetary systems, the detailed studies of protoplanetary disks, and the experimental study of the interiors and composition of the massive planets in our solar system provide a firm basis for the next big question in planet formation theory. How do the elemental and chemical compositions of planets connect with their formation? The answer to this requires that the various pieces of planet formation theory be linked together in an end-to-end picture that is capable of addressing these large data sets. In this review, we discuss the critical elements of such a picture and how they affect the chemical and elemental make up of forming planets. Important issues here include the initial state of forming and evolving disks, chemical and dust processes within them, the migration of planets and the importance of planet traps, the nature of angular momentum transport processes involving turbulence and/or MHD disk winds, planet formation theory, and advanced treatments of disk astrochemistry. All of these issues affect, and are affected by the chemistry of disks which is driven by X-ray ionization of the host stars. We discuss how these processes lead to a coherent end-to-end model and how this may address the basic question.

Accepted by Handbook of Exoplanets

http://arxiv.org/pdf/1804.04070

Debris Disks: Probing Planet Formation

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Debris disks are the dust disks found around ∼20% of nearby main sequence stars in far-IR surveys. They can be considered as descendants of protoplanetary disks or components of planetary systems, providing valuable information on circumstellar disk evolution and the outcome of planet formation. The debris disk population can be explained by the steady collisional erosion of planetesimal belts; population models constrain where (10–100 au) and in what quantity (>1 $M_\oplus$) planetesimals (>10 km in size) typically form in protoplanetary disks. Gas is now seen long into the debris disk phase. Some of this is secondary implying planetesimals have a Solar System comet-like composition, but some systems may retain primordial gas. Ongoing planet formation processes are invoked for some debris disks, such as the continued growth of dwarf planets in an unstirred disk, or the growth of terrestrial planets through giant impacts. Planets imprint structure on debris disks in many ways; images of gaps, clumps, warps, eccentricities and other disk asymmetries, are readily explained by planets at ≫5 au. Hot dust in the region planets are commonly found (<5 au) is seen for a growing number of stars. This dust usually originates in an outer belt (e.g., from exocomets), although an asteroid belt or recent collision is sometimes inferred.

Accepted by Handbook of Exoplanets

http://arxiv.org/pdf/1804.08636

Dissertation Abstracts

Formation of stars and stellar clusters in Galactic environment

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Ph.D dissertation directed by: Prof. Ian Bonnell

Ph.D degree awarded: March 2018

Star and stellar cluster formation in spiral galaxies is one of the biggest questions of astrophysics. In this thesis, I study how star formation, and the formation of stellar clusters, proceeds using SPH simulations. These simulations model a region of 400 pc and 10^7 solar masses. Star formation is modelled through the use of sink particles which represent small groups of stars. Star formation occurs in high density regions, created by galactic spiral arm passage. The spiral shock compresses the gas and generates high density regions. Once these regions attain sufficiently high density, self-gravity becomes dominant and drives collapse and star formation. The regions fragment hierarchically, forming local small groups of stars. These fall together to form clusters, which grow through subsequent mergers and large scale gas infall. As the individual star formation occurs over large distances before forming a stellar cluster, this process can result in significant age spreads of 1-2 Myrs. One protocluster is found to fail to merge due to the large scale tidal forces from the nearby regions, and instead expands forming a dispersed population of young stars such as an OB association.

https://research-repository.st-andrews.ac.uk/handle/10023/13229

Molecular clouds: magnetohydrodynamics, gravitational collapse and turbulence

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Ph.D degree awarded: February 2018

In my Ph.D. I studied the stability and contraction of molecular clouds both in the hydrodynamical and magnetohydrodynamical case, in the quasi-static and dynamical phase of evolution.

Under the hypothesis that the observed filaments and cores can be represented by a sequence of static models, I modelled the observed radial density profiles of filamentary molecular clouds observed by the Herschel satellite with h a polytropic equation of state, stressing the need of non-thermal support provided by magnetic fields or turbulence. I then introduced a helical magnetic field in the model, showing that the ratio between the poloidal and the toroidal components components (pitch angle) determines whether the filament is compressed (supported) by the toroidal (poloidal) field and confirming that magnetic field is an important ingredient determining the stability of filamentary structures.

After the stability analysis I tackled the problem of gravitational collapse in presence of turbulence. I studied the growth of small-scale density perturbation during the hydrodynamical collapse of a molecular core in the case of Hubble-like isotropic contraction and radial free-fall. I used the advanced ECHO code to perform 2D numerical simulations to compare with analytical results. I analytically estimated the transition time to non-linear regime in analogy with the Burgers equation, pointing out that the formation of shocks and the subsequent dissipation prevents the onset of gravitationally unstable perturbations.

In the last year of my Ph.D, I studied the temporal evolution of a magnetised turbulent fluid element contracting along the mean magnetic field direction, in order to determine the condition for amplification and quenching of the turbulent fluctuations. I performed fully 3D MHD simulations with the ECHO code, studying the evolution of integrated quantities, like the density contrast. I showed that turbulence is sustained when the contraction time-scale and the dissipation time-scale are comparable.

Summary of Upcoming Meetings

EPoS 2018 The Early Phase of Star Formation - Archetypes
13 - 18 May 2018, Ringberg Castle, Tegernsee, Germany
http://www.mpia.de/homes/stein/EPoS/epos.php

Interstellar: The Matter
14 - 18 May 2018, Cozumel, Mexico
http://bigbang.nucleares.unam.mx/astroplasmas/interstellar-the-matter

Cloudy workshop
14 - 25 May 2018, Chiang Mai, Thailand
http://www.narit.or.th/en/index.php/cloudy

From Prestellar Cores to Solar Nebulae
14 May - 22 June 2018, Paris-Saclay, France
https://www.ias.u-psud.fr/core2disk/

Formation of substellar objects: theory and observation
21-23 May 2018, ESAC, Madrid, Spain
http://www.laeff.cab.inta-csic.es/projects/ws18/main/index.php

The Olympian Symposium 2018: Gas and stars from milli- to mega- parsecs
28 May - 1 June 2018, Mt. Olympus, Greece
http://www.olympiansymposium.org

Cosmic Rays and the Inter Stellar Medium
25 - 29 June 2018, Grenoble, France
https://crism2008.sciencesconf.org/

Tracing the Flow: Galactic Environments and the Formation of Massive Stars
2 - 6 July 2018, Lake Windermere, UK
http://almaost.jb.man.ac.uk/meetings/TtF

The Laws of Star Formation: from the Cosmic Dawn to the Present Universe
2 - 6 July 2018, Cambridge, UK
http://www.ast.cam.ac.uk/meetings/2018/sf.law2018.cambridge

The Cosmic Cycle of Dust and Gas in the Galaxy: from Old to Young Stars
9 - 13 July 2018, Quy Nhon, Vietnam
https://cosmiccycle2018.sciencesconf.org

Astrochemistry: Past, Present, and Future
10 - 13 July, 2018, Pasadena, USA
http://www.cfa.harvard.edu/events/2018/astrochem18

Summer School on Origins of the Solar System
16 - 20 July, 2018, Taipei, Taiwan
http://events.asiaa.sinica.edu.tw/school/20180716/

COSPAR 2018 sessions on Planet Formation and Exoplanets
14 - 22 July 2018, Pasadena, USA
https://www.cospar-assembly.org/admin/sessioninfo.php?session=744

Cool Stars 20: Cambridge Workshop on Cool Stars, Stellar Systems and the Sun
29 July - 3 August 2018, Cambridge/Boston, USA
http://www.coolstars20.com

Origins: From the Protosun to the First Steps of Life
20 - 23 August 2018, Vienna, Austria
http://ninlil.elte.hu/IAUS345/

Star Cluster Formation: Mapping the first few Myrs
29 - 31 August 2018, Grenoble, France
https://sfm.leeds.ac.uk/registerinterest/

Magnetic fields along the star-formation sequence: bridging polarization-sensitive views
30-31 August 2018, Vienna, Austria
http://escience.aip.de/iau30-fm4/

The Wonders of Star Formation
3 - 7 September 2018, Edinburgh, Scotland
http://events.ph.ed.ac.uk/star-formation

Triple Evolution and Dynamics
10 - 14 September 2018, Leiden, The Netherlands
http://www.lorentzcenter.nl/lc/web/2018/1016/info.php3?wsid=1016&venue=Oort

Take a Closer Look - The Innermost Region of Protoplanetary Discs and its Connection to the Origin of Planets
15 - 19 October 2018, ESO Headquarters, Garching, Germany
http://www.eso.org/sci/publications/announcements/sciann17072.html

Zooming in on Star Formation - A tribute to Åke Nordlund
9 - 14 June 2019, Nafplio, Greece
http://www.nbia.dk/nbia-zoomstarform-2019

Abstract submission deadline

The deadline for submitting abstracts and other submissions is the first day of the month.