THE STAR FORMATION NEWSLETTER

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

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The Star Formation Newsletter

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

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Cover Picture

The image, obtained with the Hubble Space Telescope, shows photoevaporating dense clouds located within the Carina Nebula.

Image courtesy NASA, ESA, N. Smith (University of California, Berkeley), and The Hubble Heritage Team (STScI/AURA)

Submitting your abstracts

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

Chris McKee

in conversation with Bo Reipurth

Q: *Back in 1970 you defended your dissertation on cosmic ray acceleration by supernovae. How did you get to that topic?*

A: When I arrived at Berkeley as a graduate student in Physics, I did not know what kind of physics I wanted to do. I had the great good fortune to work with Stirling Colgate at Livermore during the summer after my first year as a graduate student. At that time he was carrying out the very first numerical simulations of core collapse supernovae with Dick White. He realized that the shock wave accompanying the explosion would accelerate near the surface of the star, reaching relativistic velocities if the presupernova star was sufficiently compact, and he proposed that this was the origin of cosmic rays. Meanwhile, he was also carrying out numerical simulations of the structure of collisionless shocks, finding that they could arise in one dimension due to electrostatic streaming instabilities. I realized that if his results for non-relativistic shocks extended to relativistic ones, then these two results were incompatible: the cosmic rays produced by the supernova would drive a shock into the ambient ISM and lose all their energy in adiabatic expansion. I therefore decided to see whether two plasmas streaming through each other at relativistic velocities would create a shock. My second good fortune was to have George Field as a supervisor, since he allowed me to pursue my idea. What I found was that Colgate's collisionless shocks were due to numerical effects. It is now believed that in the absence of an initial magnetic field, collisionless shocks form via electromagnetic instabilities that are intrinsically multi-dimensional, so I would not have been able to see the shock in my one-dimensional simulations, which were the state of the art in the 1960's.

Q: *Your most cited paper, with more than 1800 citations, is an early work from 1977, in which you with Jerry Ostriker developed a theory of the interstellar medium with three components regulated by supernovae. What accounts for the success and longevity of this work?*

A: An interesting question. I believe it was Martin Rees who said that this paper has the highest ratio of citations to people who have read the paper. (He made that comment a number of years ago, so I hope that is no longer true!) I attribute its longevity to two main factors: First, it generalized the work of Cox on the hot component of the interstellar medium to incorporate all the atomic components of the ISM, including the warm ionized one. The paper was closely connected to observation, providing a good way of organizing the data on the ISM. Second, it directly related the most powerful feedback effect from star formation—supernovae—to the properties of the ISM, which is just what is needed for simulations of galaxy evolution.

Q: *Over the years you have written many papers with your collaborators on astrophysical shocks. Is this subject now fully understood?*

A: A lot of progress has been made since the last review I wrote on this topic, which was with Bruce Draine in the 1993 ARAA. Perhaps the most dramatic progress is on relativistic collisionless shocks, which Spitkovsky and his students have worked on. However, many of the problems that Bruce and I pointed to in 1993 still remain: What is the ratio of the electron temperature to the ion temperature in a collisionless shock? Observation and theory both indicate significant collisionless heating, but accurate predictions cannot be made yet. It is known that particle acceleration affects the structure of shocks, but the range of scales involved, from plasma length scales like the electron skin depth to the radius of the shock, is so large that it has so far defied efforts at simulation. I think that observation will be a key driver for future progress since the remaining problems in shock structure are so challenging.

Q: *In the late 1980s you wrote a much cited paper on star formation regulated by photoionization. What were the key points?*

A: That was the first paper I wrote that focused on the process of star formation. The first key point was that much of a giant molecular cloud is photoionized by Galactic FUV radiation–i.e., much of a GMC is what we now call a PDR. The second point was based on the assumption that low-mass star formation was regulated by ambipolar diffusion, which was the standard view at that time. Since ionization suppresses ambipolar diffusion, I concluded that star formation would be suppressed in the outer parts of GMCs and would occur primarily in the inner parts, where the ionization was due to cosmic rays. We now know that most star-forming clouds are magnetically supercritical (gravitational forces exceed magnetic ones) so that ambipolar diffusion is not necessary for star formation. Interestingly enough, observations show that star formation is suppressed in the outer parts of GMCs, as I suggested. The final point was that GMCs could be held in approximate virial equilibrium by energy injection from protostellar outflows, as originally suggested by Norman and Silk. I envisioned that GMCs would form at low column densities and contract since star formation is suppressed; when the cloud contracted enough that the extinction reached 4 - 8 magnitudes, the inner parts of the GMC would be shielded so that star formation could proceed and the cloud would settle into an equilibrium state. Based on the information available at that time, I assumed that the damping time of the turbulence was of order 5 free-fall times, whereas now we know that it is less than a crossing time. Nonetheless, as I showed with Goldbaum, Krumholz and Matzner in 2011, feedback from star formation plus energy injection by accretion can result in quasi-equilibrium clouds. A prediction of this model was that clouds should be characterized by a constant extinction rather than a constant column density, and this is qualitatively consistent with observations of molecular clouds in low-metallicity galaxies.

Q: *You have a longstanding interest in the formation of massive stars, and wrote, together with Jonathan Tan, a paper on the topic in 2003. What were the new insights, and how has the model held up over the past decade?*

A: The classical Shu theory for star formation has an accretion rate proportional to $T^{3/2}$. For a temperature of 20 K, typical of a star-forming GMC, this leads to a star formation time of order 2×10^5 yr for a 1 $M_\odot$ star, in good agreement with observation. However, for a 100 $M_\odot$ star, the formation time becomes 20 Myr, far longer than the 3 Myr lifetime of the star. As early as 1980, Frank Shu pointed out that his result for the accretion rate could be extended to the case in which the isothermal sound speed was replaced by the rms thermal plus turbulent plus Alfven velocity. Later, Myers and Fuller (1992) developed an accretion model in which non-thermal motions dominated at late times and increased the rate of accretion. At one of the last (and possibly the last–as I recall it was in 2001) summer conferences organized by the Center for Star Formation Studies, which was supported by the NASA Astrophysics Theory Program for about 20 years, I realized that making this replacement would solve the time scale problem. In fact, based on observations of regions of massive star formation, I estimated that the time required to form a massive star was of order 10^5 yr. When I made this point in a special talk that was inserted into the conference program, Frank said that my conclusion was obvious, which is true. Sometimes the obvious is not apparent, however, and even today one can find papers in which it is assumed that massive stars take of order 1 Myr or more to form. I worked with Jonathan Tan to turn this basic idea into a model for massive star formation, relying heavily on prior work by McLaughlin and Pudritz in which they worked out the accretion rate for a singular polytropic sphere. We emphasized that the surface densities of star clusters such as the Orion Nebula Cluster and Galactic globular clusters were of the same order as those of the high-mass star-forming clumps observed by Plume et al (1997), ~ 1 g cm^{-2}. In this model, high-mass star formation is similar to low-mass star formation, but accelerated by the fact that the effective sound speed is larger due to the inclusion of turbulence and magnetic fields. Since then, Jonathan has extended the model so that it can be directly compared with observation. He has gathered data with a number of telescopes, including ALMA and SOFIA, and has shown that the data are reasonably consistent with the model. Recently, Norm Murray and collaborators have extended the model further by predicting the density profile around the protostar (a 3/2 power law) rather than taking that value from observation as Jonathan and I did. (There are other differences as well, but this is the key one in my mind.) Recent observations that are consistent with the Turbulent Core model include detections of massive pre-stellar core candidates (Kong et al 2017); slow rates of clump infall (Wyrowski et al 2016); limited fragmentation around massive protostars (Csengari et al 2017); and disks around massive protostars (e.g., Ilee et al 2016).

This Turbulent Core model is often contrasted with the Competitive Accretion model, which was first suggested by Hans Zinnecker and has been developed by Ian Bonnell and his collaborators. The key difference between the two models is that the Turbulent Core model is based on the assumption that stars form out of gas “cores” in the star-forming clump, whereas Competitive Accretion is based on the assumption that protostars grow by accreting gas from the entire clump at a rate that depends on the protostellar mass. There is some overlap in the two theories: The initial protostellar seeds that form in the Competitive Accretion model form out of low-mass cores, just as in the case of low-mass stars in the Turbulent Core model, and the cores in the Turbulent Core model generally accrete gas from the surroundings while the protostar grows, just as protostars do in the Competitive Accretion model. Nonetheless, one can approximately predict the mass of the star that will form from observations of the ambient gas in the Turbulent Core model, whereas that is not possible in the Competitive Accretion model; instead, one can predict the *relative* masses of the stars that will form from observations of their masses at an earlier time. The theory of the IMF that has been developed in recent years by Padoan and Nordlund, Hennebelle and Chabrier, and Hopkins are all based on the underlying principle of the Turbulent Core model: These theories predict the masses of the cores that form in a turbulent medium and then assume that the core mass determines the final stellar mass; in other words, there is a direct connection between the core mass function and the stellar initial mass function.

Q: *Your 2007 Annual Review article with Eve Ostriker on The Theory of Star Formation has already received a thousand citations. It provides a comprehensive view of the many processes involved in star formation. What aspects remain to be tackled before we can claim that star formation is fully understood?*

A: Let me respond to this from a theoretical perspective. Unsolved problems in astrophysics are challenging because of the enormous range of scales involved, and this is particularly true for star formation. The molecular clouds out of which stars form have time scales measured in millions of years, whereas solar type stars have oscillation periods measured in minutes. Many of the major questions in star formation–what determines the rate at which stars form? what determines the IMF? what determines the initial cluster mass function–are intrinsically multi-scale problems. Great progress has been made in simulations since the time of our review, but the scale problem has not gone away. Computational techniques such as SPH and AMR are used to increase the dynamic range, but they do not overcome the problem that the initial conditions on scales outside the initial dynamic range are omitted. For example, in a large-scale simulation in which GMCs are allowed to form naturally, the nonlinear density fluctuations on the scale of the sonic length cannot be treated with today's computers; in a small-scale simulation in which the sonic length is well resolved, it is necessary to either artificially continue to drive the turbulence or allow it to decay, which is unphysical since in reality it would be continuously fed from larger scales.

In terms of physical processes, there are a number that require more understanding. Most simulations that include magnetic fields assume quasi-ideal MHD – "quasi" because simulations have a numerical resistivity. It is possible to add terms corresponding to ambipolar diffusion, Hall conductivity and resistivity, but that often requires significantly greater computational time. However, magnetic reconnection is also an important non-ideal process, but it is not well understood. Lazarian and his collaborators have argued that reconnection in turbulent media is very efficient and leads to major deviations from flux freezing. Indeed, my colleagues and I see significant deviations from flux freezing in our ideal MHD simulations, and turbulent reconnection is a possible explanation. The physics of reconnection is complex, however, and it is far from clear that numerical resistivity provides an adequate approximation for simulating its effects.

Interstellar dust provides many unsolved problems. It is generally assumed that the dust-to-gas ratio is constant, whereas in fact radiation pressure is generally far more important for dust than for gas, which could lead to significant variations in the dust-to-gas ratio. It is also generally assumed that the composition of dust is spatially uniform, apart from allowing for the observed fact that grains are larger in denser regions. However, grain growth and destruction vary in both space and time, so it is quite likely that there are significant local variations in the grain composition even though observations show that the average properties over long sight lines are fairly uniform. PAHs can have a large effect on the ionization of weakly ionized gas, so the variations in their abundance is of particular interest.

The challenges I have mentioned are just examples. The good news is that powerful instruments are providing new data that, in combination with continued advances in theory and simulation, I hope will point the way toward achieving a greater understanding of how stars form.

Q: *Binaries are ubiquitous among the youngest stars. What are your views on the formation of binaries and multiple systems?*

A: I don't understand binaries. Matthew Bate published a very nice radiation hydrodynamical simulation of the formation of a cluster of stars in 2012. He found a distribution of binary separations that was consistent with observation after allowing for the fact that his simulation, which agreed well with the observed IMF, had more low-mass stars than did the observed binary sample. How is that possible when it is known that magnetic fields, which he did not include, are known to have a major effect in extracting angular momentum from the accreting gas? In fact, in our current understanding, magnetic fields are so effective at extracting angular momentum that many simulations of the formation of protostellar disks fail to produce disks nearly as large as are observed.

Q: *In recent years you have taken an interest in the formation of the first stars. What are the main insights you have gained?*

A: There are two key differences between the formation of the first stars and contemporary star formation. The first is obvious: there were no metals when the first stars formed. As a result, cooling was much less efficient and the temperature was higher, which caused both the mass of the stars that formed to be larger and the rate at which they formed to be faster. The second difference is in the initial conditions: The first stars are believed to have formed in dark matter mini-halos with masses of order $10^5 - 10^6\, M_\odot$, so that the initial formation of nonlinear density fluctuations in the gas was due to primordial fluctuations in the dark matter, not processes in the gas. Jonathan and I argued that the masses of the first stars were limited by photoionization, and subsequent numerical simulations have shown that this is generally the case. Based on the pioneering simulations of Abel, Bryan and Norman and of Bromm, Coppi and Larson, we assumed that only single stars formed in the mini-halos. Subsequent work has shown that multiple stars can form, which is a significant complication. It also generates a puzzle: If any of these stars were less than $0.8\,M_\odot$, they would still be here; why haven't they been seen? At the time Jonathan and I worked on our model for the formation of the first stars, I assumed that the particles that make up the dark matter would have been discovered by now and that most likely they would be Weakly Interacting Massive Particles (WIMPs). However, WIMPs have not been discovered, and a wide range of alternatives are being considered. Some of these alternatives do not form mini-halos, and if one of those turns out to be true, the theory of the first stars will have to be re-thought.

Q: *What are your current interests and plans?*

A: I have retired from teaching, but I hope to continue my research, primarily in star formation. I am currently collaborating on a number of entertaining projects: A zoom-in simulation of star formation from interstellar to protostellar disk scales; a study of filamentary structure of star-forming clouds; the effects of photoionization and radiation pressure on massive star formation; and the formation of Orion-scale clusters and super star clusters. I am also collaborating on a study of how the observed IMF can differ from the actual IMF and a study of the Galactic corona. All of this will keep me busy for some time to come! Fortunately, I have a number of excellent collaborators to help me.

Abstracts of recently accepted papers

Dust dynamics and evolution in HII regions - II. Effects of dynamical coupling between dust and gas

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In this paper, we extend the study initiated in Paper I by modelling grain ensemble evolution in a dynamical model of an expanding HII region and checking the effects of momentum transfer from dust to gas. The radiation pressure on the dust, the dust drift, and the lug on the gas by the dust are all important process that should be considered simultaneously to describe the dynamics of HII regions. With accounting for the momentum transfer from the dust to the gas, the expansion time of the HII region is notably reduced (for our model of RCW120, the time to reach the observed radius of the HII region is reduced by a factor of 1.5). Under the common approximation of frozen dust, where there is no relative drift between the dust and gas, the radiation pressure from the ionizing star drives the formation of the very deep gas cavity near the star. Such a cavity is much less pronounced when the dust drift is taken into account. The dust drift leads to the two-peak morphology of the dust density distribution and significantly reduces the dust-to-gas ratio in the ionized region (by a factor of 2 to 10). The dust-to-gas ratio is larger for higher temperatures of the ionizing star since the dust grains have a larger electric charge and are more strongly coupled to the gas.

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Herschel GASPS spectral observations of T Tauri stars in Taurus: Unraveling far-infrared line emission from jets and discs

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At early stages of stellar evolution young stars show powerful jets and/or outflows that interact with protoplanetary discs and their surroundings. Despite the scarce knowledge about the interaction of jets and/or outflows with discs, spectroscopic studies based on *Herschel* and ISO data suggests that gas shocked by jets and/or outflows can be traced by far-IR (FIR) emission in certain sources. We want to provide a consistent catalogue of selected atomic ([OI] and [CII]) and molecular (CO, H_2O, and OH) line fluxes observed in the FIR, separate and characterize the contribution from the jet and the disc to the observed line emission, and place the observations in an evolutionary picture. The atomic and molecular FIR (60–190 μm) line emission of protoplanetary discs around 76 T Tauri stars located in Taurus are analysed. The observations were carried out within the *Herschel* key programme Gas in Protoplanetary Systems (GASPS). The spectra were obtained with the Photodetector Array Camera and Spectrometer (PACS). The sample is first divided in outflow and non-outflow sources according to literature tabulations. With the aid of archival stellar/disc and jet/outflow tracers and model predictions (PDRs and shocks), correlations are explored to constrain the physical mechanisms behind the observed line emission. Outflow sources exhibit brighter atomic and molecular emission lines and higher detection rates than non-outflow sources. The line detection fractions decrease with SED evolutionary status (from Class I to Class III). We find correlations between [OI] 63.18 μm and [OI] 6300 Å, o–H_2O 78.74 μm, CO 144.78 μm, OH 79.12+79.18 μm, and the continuum flux at 24 μm. The atomic line ratios can be explain either by fast ($V_{\rm shock}$ >50 km s^{-1}) dissociative J-shocks at low densities ($n \sim 10^3$ cm^{-3}) occurring along the jet and/or PDR emission ($G_0 > 10^2$, $n \sim 10^3 - 10^6$ cm^{-3}). To account for the [CII] absolute fluxes, PDR emission or UV irradiation of shocks is needed. In comparison, the molecular emission is more compact and the line ratios are better explained with slow ($V_{\rm shock}$ <40 km s^{-1}) C-type shocks with high pre-shock densities (10^4–10^6 cm^{-3}), with the exception of OH lines, that are better described by J-type shocks. Disc models alone fail to reproduce the observed molecular line fluxes, but a contribution to the line fluxes from UV-illuminated discs and/or outflow cavities is expected. Far-IR lines dominate disc cooling at early stages and weaken as the star+disc system evolves from Class I to Class III, with an increasing relative disc contribution to the line fluxes. Models which take into account jets, discs, and their mutual interaction are needed to disentangle the different components and study their evolution. The much higher detection rate of emission lines in outflow sources and the compatibility of line ratios with shock model predictions supports the idea of a dominant contribution from the jet/outflow to the line emission, in particular at earlier stages of the stellar evolution as the brightness of FIR lines depends in large part on the specific evolutionary stage.

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Fluorescent H2 Emission Lines from the Reflection Nebula NGC 7023 observed with IGRINS

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We have analyzed the temperature, velocity and density of H_2 gas in NGC 7023 with a high-resolution near-infrared spectrum of the northwestern filament of the reflection nebula. By observing NGC 7023 in the H and K bands at $R \simeq 45{,}000$ with the Immersion GRating INfrared Spectrograph (IGRINS), we detected 68 H_2 emission lines within the 1" × 15" slit. The diagnostic ratios of 2-1 S(1)/1-0 S(1) is 0.41−0.56. In addition, the estimated ortho-to-para ratios (OPR) is 1.63−1.82, indicating that the H_2 emission transitions in the observed region arises mostly from gas excited by UV fluorescence. Gradients in the temperature, velocity, and OPR within the observed area imply motion of the photodissociation region (PDR) relative to the molecular cloud. In addition, we derive the column density of H_2 from the observed emission lines and compare these results with PDR models in the literature covering a range of densities and incident UV field intensities. The notable difference between PDR model predictions and the observed data, in high rotational J levels of $\nu = 1$, is that the predicted formation temperature for newly-formed H_2 should be lower than that of the model predictions. To investigate the density distribution, we combine pixels in 1" × 1" areas and derive the density distribution at the 0.002 pc scale. The derived gradient of density suggests that NGC 7023 has a clumpy structure, including a high clump density of $\sim 10^5$ cm^{-3} with a size smaller than $\sim 5 \times 10^{-3}$ pc embedded in lower density regions of $10^3 - 10^4$ cm^{-3}.

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Star formation rates and efficiencies in the Galactic Centre

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The inner few hundred parsecs of the Milky Way harbours gas densities, pressures, velocity dispersions, an interstellar radiation field and a cosmic ray ionisation rate orders of magnitude higher than the disc; akin to the environment found in star-forming galaxies at high-redshift. Previous studies have shown that this region is forming stars at a rate per unit mass of dense gas which is at least an order of magnitude lower than in the disc, potentially violating theoretical predictions. We show that all observational star formation rate diagnostics — both direct counting of young stellar objects and integrated light measurements — are in agreement within a factor two, hence the low star formation rate is not the result of the systematic uncertainties that affect any one method. As these methods trace the star formation over different timescales, from 0.1–5 Myr, we conclude that the star formation rate has been constant to within a factor of a few within this time period. We investigate the progression of star formation within gravitationally bound clouds on ∼parsec scales and find 1–4 per cent of the cloud masses are converted into stars per free-fall time, consistent with a subset of the considered "volumetric" star formation models. However, discriminating between these models is obstructed by the current uncertainties on the input observables and, most importantly and urgently, by their dependence on ill-constrained free parameters. The lack of empirical constraints on these parameters therefore represents a key challenge in the further verification or falsification of current star formation theories.

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Interstellar extinction in Orion. Variation of the strength of the UV bump across the complex

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There is growing observational evidence of dust coagulation in the dense filaments within molecular clouds. Infrared observations show that the dust grains size distribution gets shallower and the relative fraction of small to large dust grains decreases as the local density increases. Ultraviolet (UV) observations show that the strength of the 2175 Å feature, the so-called UV bump, also decreases with cloud density. In this work, we apply the technique developed for the Taurus study to the Orion molecular cloud and confirm that the UV bump decreases over the densest cores of the cloud as well as in the heavily UV irradiated λ Orionis shell. The study has been extended to the Rosette cloud with uncertain results given the distance (1.3 kpc).

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3D radiative transfer of intrinsically polarized dust emission based on aligned aspherical grains

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(Sub-)Millimeter observations of the polarized emission of aligned aspherical dust grains enable us to study the magnetic fields within protoplanetary disk. However, the interpretation of these observations is complex. One must consider the various effects that alter the measured polarized signal, such as the shape of dust grains, the efficiency of grain alignment, the magnetic field properties, and the projection of the signal along the line of sight. We aim at analyzing observations of the polarized dust emission by disentangling the effects on the polarization signal in the context of 3D radiative transfer simulations. For this purpose, we developed a code capable of simulating dust grain alignment of aspherical grains and intrinsical polarization of thermal dust emission. We find that the influence of thermal polarization and dust grain alignment on the polarized emission displayed as spatially resolved polarization map or as spectral energy distribution trace disk properties which are not traced in total (unpolarized) emission such as the magnetic field topology. The radiative transfer simulations presented in this work enable the 3D analysis of intrinsically polarized dust emission - observed with, e.g., ALMA - which is essential to constrain magnetic field properties.

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A Close-up View of the Young Circumbinary Disk HD 142527

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We present ALMA observations of the 0.88 millimeter dust continuum, ^{13}CO, and C^{18}O J=3–2 line emission of the circumbinary disk HD142527 at a spatial resolution of about $0\farcs25$. This system is characterized by a large central cavity of roughly 120 AU in radius, and asymmetric dust and gas emission. By comparing the observations with theoretical models, we find that the azimuthal variations in gas and dust density reach a contrast of 54 for dust grains and 3.75 for CO molecules, with an extreme gas-to-dust ratio of 1.7 on the dust crescent. We point out that caution is required in interpreting continuum subtracted maps of the line emission as this process might result in removing a large fraction of the line emission. Radially, we find that both the gas and dust surface densities can be described by Gaussians, centered at the same disk radius, and with gas profiles wider than for the dust. These results strongly support a scenario in which millimeter dust grains are radially and azimuthally trapped toward the center of a gas pressure bump. Finally, our observations reveal a compact source of continuum and CO emission inside the dust depleted cavity at about 50 AU from the primary star. The kinematics of the CO emission from this region is different from that expected from material in Keplerian rotation around the binary system, and might instead trace a compact disk around a third companion. Higher angular resolution observations are required to investigate the nature of this source.

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The Northern Arc of ϵ Eridani's Debris Ring as Seen by ALMA

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We present the first ALMA observations of the closest known extrasolar debris disc. This disc orbits the star ϵ Eridani, a K-type star just 3.2 pc away. Due to the proximity of the star, the entire disc cannot fit within the ALMA field of view. Therefore, the observations have been centred 18 arcsec North of the star, providing us with a clear detection of the northern arc of the ring, at a wavelength of 1.3 mm. The observed disc emission is found to be narrow with a width of just 11-13 AU. The fractional disc width we find is comparable to that of the Solar System's Kuiper Belt and makes this one of the narrowest debris discs known. If the inner and outer edges are due to resonances with a planet then this planet likely has a semi-major axis of 48 AU. We find tentative evidence for clumps in the ring, although there is a strong chance that at least one is a background galaxy. We confirm, at much higher significance, the previous detection of an unresolved emission at the star that is above the level of the photosphere and attribute this excess to stellar chromospheric emission.

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Terrestrial planet formation: Dynamical shake-up and the low mass of Mars

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We consider a dynamical shake-up model to explain the low mass of Mars and the lack of planets in the asteroid belt. In our scenario, a secular resonance with Jupiter sweeps through the inner solar system as the solar nebula depletes, pitting resonant excitation against collisional damping in the Suns protoplanetary disk. We report the outcome of extensive numerical calculations of planet formation from planetesimals in the terrestrial zone, with and without dynamical shake-up. If the Suns gas disk within the terrestrial zone depletes in roughly a million years, then the sweeping resonance inhibits planet formation in the asteroid belt and substantially limits the size of Mars. This phenomenon likely occurs around other stars with long-period massive planets, suggesting that asteroid belt analogs are common.

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Kiloparsec-Scale Simulations of Star Formation in Disk Galaxies. IV. Regulation of Galactic Star Formation Rates by Stellar Feedback

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Star formation from the interstellar medium of galactic disks is a basic process controlling the evolution of galaxies. Understanding the star formation rate in a local patch of a disk with a given gas mass is thus an important challenge for theoretical models. Here we simulate a kiloparsec region of a disk, following the evolution of self-gravitating molecular clouds down to subparsec scales, as they form stars that then inject feedback energy by dissociating and ionizing UV photons and supernova explosions. We assess the relative importance of each feedback mechanism. We find that H_2-dissociating feedback results in the largest absolute reduction in star formation compared to the run with no feedback. Subsequently adding photoionization feedback produces a more modest reduction. Our fiducial models that combine all three feedback mechanisms yield, without fine-tuning, star formation rates that are in excellent agreement with observations, with H_2-dissociating photons playing a crucial role. Models that only include supernova feedback—a common method in galaxy evolution simulations—settle to similar star formation rates, but with very different temperature and chemical states of the gas, and with very different spatial distributions of young stars.

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The SOFIA Massive (SOMA) Star Formation Survey: I. Overview and First Results

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We present an overview and first results of the *SOFIA* Massive (SOMA) Star Formation Survey, which is using the FORCAST instrument to image massive protostars from ~ 10–$40\,\mu$m. These wavelengths trace thermal emission from warm dust, which in Core Accretion models mainly emerges from the inner regions of protostellar outflow cavities. Dust in dense core envelopes also imprints characteristic extinction patterns at these wavelengths causing intensity peaks to shift along the outflow axis and profiles to become more symmetric at longer wavelengths. We present observational results for the first eight protostars in the survey, i.e., multiwavelength images, including some ancillary ground-based MIR observations and archival *Spitzer* and *Herschel* data. These images generally show extended MIR/FIR emission along directions consistent with those of known outflows and with shorter wavelength peak flux positions displaced from the protostar along the blue-shifted, near-facing sides, thus confirming qualitative predictions of Core Accretion models. We then compile spectral energy distributions and use these to derive protostellar properties by fitting theoretical radiative transfer models. Zhang & Tan models, based on the Turbulent Core Model of McKee & Tan,

imply the sources have protostellar masses $m_* \sim 10$–$50\,M_\odot$ accreting at $\sim 10^{-4}$–$10^{-3}\,M_\odot\,\mathrm{yr}^{-1}$ inside cores of initial masses $M_c \sim 30$–$500\,M_\odot$ embedded in clumps with mass surface densities $\Sigma_{\rm cl} \sim 0.1$–$3\,\mathrm{g\,cm}^{-2}$. Fitting Robitaille et al. models typically leads to slightly higher protostellar masses, but with disk accretion rates $\sim 100\times$ smaller. We discuss reasons for these differences and overall implications of these first survey results for massive star formation theories.

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The extended law of star formation: the combined role of gas and stars

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We present a model for the origin of the extended law of star formation in which the surface density of star formation ($\Sigma_{\rm SFR}$) depends not only on the local surface density of the gas (Σ_g), but also on the stellar surface density (Σ_*), the velocity dispersion of the stars, and on the scaling laws of turbulence in the gas. We compare our model with the spiral, face-on galaxy NGC 628 and show that the dependence of the star formation rate on the entire set of physical quantities for both gas and stars can help explain both the observed general trends in the $\Sigma_g - \Sigma_{\rm SFR}$ and $\Sigma_* - \Sigma_{\rm SFR}$ relations, but also, and equally important, the scatter in these relations at any value of Σ_g and Σ_*. Our results point out to the crucial role played by existing stars along with the gaseous component in setting the conditions for large scale gravitational instabilities and star formation in galactic disks.

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An opening criterion for dust gaps in protoplanetary discs

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We aim to understand under which conditions a low mass planet can open a gap in viscous dusty protoplanetary discs. For this purpose, we extend the theory of dust radial drift to include the contribution from the tides of an embedded planet and from the gas viscous forces. From this formalism, we derive i) a grain size-dependent criterion for dust gap opening in discs, ii) an estimate of the location of the outer edge of the dust gap and iii) an estimate of the minimum Stokes number above which low-mass planets are able to carve gaps which appear only in the dust disc. These analytical estimates are particularly helpful to appraise the minimum mass of an hypothetical planet carving gaps in discs observed at long wavelengths and high resolution. We validate the theory against 3D SPH simulations of planet-disc interaction in a broad range of dusty protoplanetary discs. We find a remarkable agreement between the theoretical model and the numerical experiments.

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The JCMT Plane Survey: first complete data release - emission maps and compact source catalogue

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We present the first data release of the James Clerk Maxwell Telescope (JCMT) Plane Survey (JPS), the JPS Public Release 1 (JPSPR1). JPS is an 850-μm continuum survey of six fields in the northern inner Galactic Plane in a longitude range of $\ell = 7°–63°$, made with the Sub-millimetre Common-User Bolometer Array 2 (SCUBA-2). This first data release consists of emission maps of the six JPS regions with an average pixel-to-pixel noise of 7.19 mJy beam^{-1}, when smoothed over the beam, and a compact-source catalogue containing 7,813 sources. The 95 per cent completeness limits of the catalogue are estimated at 0.04 Jy beam^{-1} and 0.3 Jy for the peak and integrated flux densities, respectively.

The emission contained in the compact-source catalogue is 42 ± 5 per cent of the total and, apart from the large-scale (greater than 8 arcmin) emission, there is excellent correspondence with features in the 500-μm *Herschel* maps. We find that, with two-dimensional matching, 98 ± 2 per cent of sources within the fields centred at $\ell = 20°$, 30°, 40° and 50° are associated with molecular clouds, with 91 ± 3 per cent of the $\ell = 30°$ and 40° sources associated with dense molecular clumps. Matching the JPS catalogue to *Herschel* 70-μm sources, we find that 38 ± 1 per cent of sources show evidence of ongoing star formation. The images and catalogue will be a valuable resource for studies of star formation in the Galaxy and the role of environment and spiral arms in the star formation process.

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The Dispersal of Planet-forming discs: Theory confronts Observations

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Discs of gas and dust around Myr-old stars are a by-product of the star formation process and provide the raw material to form planets. Hence, their evolution and dispersal directly impact what type of planets can form and affect the final architecture of planetary systems. Here, we review empirical constraints on disc evolution and dispersal with special emphasis on transition discs, a subset of discs that appear to be caught in the act of clearing out planet-forming material. Along with observations, we summarize theoretical models that build our physical understanding of how discs evolve and disperse and discuss their significance in the context of the formation and evolution of planetary systems. By confronting theoretical predictions with observations, we also identify the most promising areas for future progress.

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ALMA Observations of Asymmetric Molecular Gas Emission from a Protoplanetary Disk in the Orion Nebula

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We present Atacama Large Millimeter/submillimeter Array (ALMA) observations of molecular line emission from d216-0939, one of the largest and most massive protoplanetary disks in the Orion Nebula Cluster (ONC). We model the spectrally resolved HCO^+ (4–3), CO (3–2), and HCN (4–3) lines observed at 0.5" resolution to fit the temperature and density structure of the disk. We also weakly detect and spectrally resolve the CS (7–6) line but do not model it. The abundances we derive for CO and HCO^+ are generally consistent with expected values from chemical modeling of protoplanetary disks, while the HCN abundance is higher than expected. We dynamically measure the mass of the central star to be $2.17 \pm 0.07\, M_\odot$ which is inconsistent with the previously determined spectral type of K5. We also report the detection of a spatially unresolved high-velocity blue-shifted excess emission feature with a measurable positional offset from the central star, consistent with a Keplerian orbit at 60 ± 20 au. Using the integrated flux of the feature in HCO^+ (4–3), we estimate the total H_2 gas mass of this feature to be at least $1.8 - 8\,M_{\rm Jupiter}$, depending on the assumed temperature. The feature is due to a local temperature and/or density enhancement consistent with either a hydrodynamic vortex or the expected signature of the envelope of a forming protoplanet within the disk.

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The *Herschel* Orion Protostar Survey: Luminosity and Envelope Evolution

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The *Herschel* Orion Protostar Survey obtained well-sampled 1.2 – 870 μm spectral energy distributions (SEDs) of over 300 protostars in the Orion molecular clouds, home to most of the young stellar objects (YSOs) in the nearest 500 pc. We plot the bolometric luminosities and temperatures for 330 Orion YSOs, 315 of which have bolometric temperatures characteristic of protostars. The histogram of bolometric temperature is roughly flat; 29% of the protostars are in Class 0. The median luminosity decreases by a factor of four with increasing bolometric temperature; consequently, the Class 0 protostars are systematically brighter than the Class I protostars, with a median luminosity of 2.3 $L_\odot$ as opposed to 0.87 $L_\odot$. At a given bolometric temperature, the scatter in luminosities is three orders of magnitude. Using fits to the SEDs, we analyze how the luminosities corrected for inclination and foreground reddening relate to the mass in the inner 2500 AU of the best-fit model envelopes. The histogram of envelope mass is roughly flat, while the median corrected luminosity peaks at 15 $L_\odot$ for young envelopes and falls to 1.7 $L_\odot$ for late-stage protostars with remnant envelopes. The spread in luminosity at each envelope mass is three orders of magnitude. Envelope masses that decline exponentially with time explain the flat mass histogram and the decrease in luminosity, while the formation of a range of stellar masses explains the dispersion in luminosity.

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The Green Bank Ammonia Survey (GAS): First results of NH_3 mapping the Gould Belt

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We present an overview of the first data release (DR1) and first-look science from the Green Bank Ammonia Survey (GAS). GAS is a Large Program at the Green Bank Telescope to map all Gould Belt star-forming regions with $A_V \gtrsim 7$ mag visible from the northern hemisphere in emission from NH_3 and other key molecular tracers. This first release includes the data for four regions in Gould Belt clouds: B18 in Taurus, NGC 1333 in Perseus, L1688 in Ophiuchus, and Orion A North in Orion. We compare the NH_3 emission to dust continuum emission from *Herschel*, and find that the two tracers correspond closely. NH_3 is present in over 60 % of lines-of-sight with $A_V \gtrsim 7$ mag in three of the four DR1 regions, in agreement with expectations from previous observations. The sole exception is B18, where NH_3 is detected toward ~ 40 % of lines-of-sight with $A_V \gtrsim 7$ mag. Moreover, we find that the NH_3 emission is generally extended beyond the typical 0.1 pc length scales of dense cores. We produce maps of the gas kinematics, temperature, and NH_3 column densities through forward modeling of the hyperfine structure of the NH_3 (1,1) and (2,2) lines. We show that the NH_3 velocity dispersion, σ_v, and gas kinetic temperature, T_K, vary systematically between the regions included in this release, with an increase in both the mean value and spread of σ_v and T_K with increasing star formation activity. The data presented in this paper are publicly available.

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Electron Excitation of High Dipole Moment Molecules Reexamined

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Emission from high–dipole moment molecules such as HCN allows determination of the density in molecular clouds, and is often considered to trace the "dense" gas available for star formation. We assess the importance of electron excitation in various environments. The ratio of the rate coefficients for electrons and H_2 molecules, $\simeq 10^5$ for HCN, yields the requirements for electron excitation to be of practical importance if $n(H_2) \leq 10^{5.5}$ cmv and $X(e^-) \geq 10^{-5}$, where the numerical factors reflect critical values $n_c(H_2)$ and $X^*(e^-)$. This indicates that in regions where a large fraction of carbon is ionized, $X(e^-)$ will be large enough to make electron excitation significant. The situation is in

general similar for other "high density tracers", including HCO^+, CN, and CS. But there are significant differences in the critical electron fractional abundance, $X^*(e^-)$, defined by the value required for equal effect from collisions with H_2 and e^-. Electron excitation is, for example, unimportant for CO and C^+. Electron excitation may be responsible for the surprisingly large spatial extent of the emission from dense gas tracers in some molecular clouds (Pety et al. 2017, Kauffmann, Goldsmith et al. 2017, A&A, submitted). The enhanced estimates for HCN abundances and HCN/CO and HCN/HCO^+ ratios observed in the nuclear regions of luminous galaxies may be in part a result of electron excitation of high dipole moment tracers. The importance of electron excitation will depend on detailed models of the chemistry, which may well be non–steady state and non–static.

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Nature of shocks revealed by SOFIA OI observations in the Cepheus E protostellar outflow

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Protostellar jets and outflows are key features of the star-formation process, and primary processes of the feedback of young stars on the interstellar medium. Understanding the underlying shocks is necessary to explain how jets and outflows are launched, and to quantify their chemical and energetic impacts on the surrounding medium. We performed a high-spectral resolution study of the $[OI]_{63\mu m}$ emission in the outflow of the intermediate-mass Class 0 protostar Cep E-mm. We present observations of the OI $^3P_1 \rightarrow {}^3P_2$, OH between $^2\Pi_{1/2}$ $J = 3/2$ and $J = 1/2$ at 1837.8 GHz, and CO (16–15) lines with SOFIA-GREAT at three positions in the Cep E outflow: mm (the driving protostar), BI (in the southern lobe), and BII (the terminal position in the southern lobe). The CO line is detected at all three positions. The $[OI]_{63\mu m}$ line is detected in BI and BII, whereas the OH line is not detected. In BII, we identify three kinematical components in OI and CO, already detected in CO: the jet, the HH377 terminal bow-shock, and the outflow cavity. The OI column density is higher in the outflow cavity than in the jet, which itself is higher than in the terminal shock. The terminal shock is where the abundance ratio of OI to CO is the lowest (about 0.2), whereas the jet component is atomic (ratio $\sim$2.7). In the jet, we compare the $[OI]_{63\mu m}$ observations with shock models that successfully fit the integrated intensity of 10 CO lines: these models do not fit the $[OI]_{63\mu m}$ data. The high intensity of OI emission points towards the propagation of additional dissociative or alternative FUV-irradiated shocks, where the illumination comes from the shock itself. From the sample of low-to-high mass protostellar outflows where similar observations have been performed, the effects of illumination seem to increase with the mass of the protostar.

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Detection of interstellar ortho-D_2H^+ with SOFIA

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We report on the detection of the ground-state rotational line of ortho-D_2H^+ at 1.477 THz (203 μm) using the German REceiver for Astronomy at Terahertz frequencies (GREAT) on board the Stratospheric Observatory For Infrared Astronomy (SOFIA). The line is seen in absorption against far-infrared continuum from the protostellar binary IRAS 16293-2422 in Ophiuchus. The para-D_2H^+ line at 691.7 GHz was not detected with the APEX telescope toward this position. These D_2H^+ observations complement our previous detections of para-H_2D^+ and ortho-H_2D^+ using SOFIA and APEX. By modeling chemistry and radiative transfer in the dense core surrounding the protostars, we find that the ortho-D_2H^+ and para-H_2D^+ absorption features mainly originate in the cool ($T < 18$ K) outer envelope of the core. In contrast, the ortho-H_2D^+ emission from the core is significantly absorbed by the ambient molecular cloud. Analyses of the combined D_2H^+ and H_2D^+ data result in an age estimate of $\sim 5 \times 10^5$ yr for the core, with an uncertainty of $\sim 2 \times 10^5$ yr. The core material has probably been pre-processed for another 5×10^5 years in conditions corresponding to those in the ambient molecular cloud. The inferred time scale is more than 10 times the age of the embedded protobinary. The D_2H^+ and H_2D^+ ions have large and nearly equal total (ortho+para) fractional abundances of $\sim 10^{-9}$ in the outer envelope. This confirms the central role of H_3^+ in the deuterium chemistry in cool, dense gas, and adds support to the prediction of chemistry models that also D_3^+ should be abundant in these conditions.

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Spread of the dust temperature distribution in circumstellar disks

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Accurate temperature calculations for circumstellar disks are particularly important for their chemical evolution. Their temperature distribution is determined by the optical properties of the dust grains, which, among other parameters, depend on their radius. However, in most disk studies, only average optical properties and thus an average temperature is assumed to account for an ensemble of grains with different radii. We investigate the impact of subdividing the grain radius distribution into multiple sub-intervals on the resulting dust temperature distribution and spectral energy distribution (SED). The temperature distribution, the relative grain surface below a certain temperature, the freeze-out radius, and the SED were computed for two different scenarios: (1) Radius distribution represented by 16 logarithmically distributed radius intervals, and (2) radius distribution represented by a single grain species with averaged optical properties (reference). Within the considered parameter range, i.e., of grain radii between 5 nm and 1 mm and an optically thin and thick disk with a parameterized density distribution, we obtain the following results: In optically thin disk regions, the temperature spread can be as large as $\sim 63\%$ and the relative grain surface below a certain temperature is lower than in the reference disk. With increasing optical depth, the difference in the midplane temperature and the relative grain surface below a certain temperature decreases. Furthermore, below ~ 20 K, this fraction is higher for the reference disk than for the case of multiple grain radii, while it shows the opposite behavior for temperatures above this threshold. The thermal emission in the case of multiple grain radii at short wavelengths is stronger than for the reference disk. The freeze-out radius (snowline) is a function of grain radius, spanning a radial range between the coldest and warmest grain species of ~ 30 AU.

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Making Terrestrial Planets: High Temperatures, FU Orionis Outbursts, Earth, and Planetary System Architectures

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Current protoplanetary dust coagulation theory does not predict dry silicate planetesimals, in tension with the Earth. While remedies to this predicament have been proposed, they have generally failed numerical studies, or are in tension with the Earth's (low, volatility dependent) volatile and moderately volatile elemental abundances. Expanding on the work of Boley et al. (2014), we examine the implications of molten grain collisions and find that they may provide a solution to the dry silicate planetesimal problem. Further, the source of the heating, be it the hot inner disk or an FU Orionis scale accretion event, would dictate the location of the resulting planetesimals, potentially controlling subsequent planetary system architectures. We hypothesize that systems which did undergo FU Orionis scale accretion events host planetary systems similar to our own, while ones that did not instead host very close in, tightly packed planets such as seen by Kepler.

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Radial Surface Density Profiles of Gas and Dust in the Debris Disk around 49 Ceti

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We present ∼0.4" resolution images of CO(3-2) and associated continuum emission from the gas-bearing debris disk around the nearby A star 49 Ceti, observed with the Atacama Large Millimeter/Submillimeter Array (ALMA). We analyze the ALMA visibilities in tandem with the broad-band spectral energy distribution to measure the radial surface density profiles of dust and gas emission from the system. The dust surface density decreases with radius between $\sim$ 100 and 310 au, with a marginally significant enhancement of surface density at a radius of $\sim$ 110 au. The SED requires an inner disk of small grains in addition to the outer disk of larger grains resolved by ALMA. The gas disk exhibits a surface density profile that increases with radius, contrary to most previous spatially resolved observations of circumstellar gas disks. While ∼80% of the CO flux is well described by an axisymmetric power-law disk in Keplerian rotation about the central star, residuals at ∼20% of the peak flux exhibit a departure from axisymmetry suggestive of spiral arms or a warp in the gas disk. The radial extent of the gas disk ($\sim$ 220 au) is smaller than that of the dust disk ($\sim$ 300 au), consistent with recent observations of other gas-bearing debris disks. While there are so far only three broad debris disks with well characterized radial dust profiles at millimeter wavelengths, 49 Ceti's disk shows a markedly different structure from two radially resolved gas-poor debris disks, implying that the physical processes generating and sculpting the gas and dust are fundamentally different.

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X Marks the Spot: Nexus of Filaments, Cores, and Outflows in a Young Star-Forming Region

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We present a multiwavelength investigation of a region of a nearby giant molecular cloud that is distinguished by a minimal level of star formation activity. With our new ^{12}CO(J = 2–1) and ^{13}CO(J = 2–1) observations of a remote region within the middle of the California molecular cloud, we aim to investigate the relationship between filaments, cores, and a molecular outflow in a relatively pristine environment. An extinction map of the region from Herschel Space Observatory observations reveals the presence of two 2-pc-long filaments radiating from a high-extinction clump. Using the ^{13}CO observations, we show that the filaments have coherent velocity gradients and that their mass-per-unit-lengths may exceed the critical value above which filaments are gravitationally unstable. The region exhibits structure with eight cores, at least one of which is a starless, prestellar core. We identify a low-velocity, low-mass molecular outflow that may be driven by a flat spectrum protostar. The outflow does not appear to be responsible for driving the turbulence in the core with which it is associated, nor does it provide significant support against gravitational collapse.

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Oxygen budget in low-mass protostars: the NGC1333-IRAS4A R1 shock observed in [OI] at 63 μm with SOFIA-GREAT

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In molecular outflows from forming low-mass protostars, most oxygen is expected to be locked up in water. However, *Herschel* observations have shown that typically an order of magnitude or more of the oxygen is still unaccounted for. To test if the oxygen is instead in atomic form, SOFIA-GREAT observed the R1 position of the bright molecular outflow from NGC1333-IRAS4A. The [OI] 63 μm line is detected and spectrally resolved. From an intensity peak at +15 km s^{-1}, the intensity decreases until +50 km s^{-1}. The profile is similar to that of high-velocity (HV) H_2O and CO 16–15, the latter observed simultaneously with [OI]. A radiative transfer analysis suggests that $\sim$15% of the oxygen is in atomic form toward this shock position. The CO abundance is inferred to be $\sim 10^{-4}$ by a similar analysis, suggesting that this is the dominant oxygen carrier in the HV component. These results demonstrate that a large portion of the observed [OI] emission is part of the outflow. Further observations are required to verify whether this is a general trend.

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L1157-B1, a factory of complex organic molecules in a Solar-type star forming region

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We report on a systematic search for oxygen-bearing Complex Organic Molecules (COMs) in the Solar-like protostellar shock region L1157-B1, as part of the IRAM Large Program "Astrochemical Surveys At IRAM" (ASAI). Several COMs are unambiguously detected, some for the first time, such as ketene H_2CCO, dimethyl ether (CH_3OCH_3) and glycolaldehyde ($HCOCH_2OH$), and others firmly confirmed, such as formic acid (HCOOH) and ethanol (C_2H_5OH). Thanks to the high sensitivity of the observations and full coverage of the 1, 2 and 3 mm wavelength bands, we detected numerous (10–125) lines from each of the detected species. Based on a simple rotational diagram analysis, we derive the excitation conditions and the column densities of the detected COMs. Combining our new results with those previously obtained towards other protostellar objects, we found a good correlation between ethanol, methanol and glycolaldehyde. We discuss the implications of these results on the possible formation routes of ethanol and glycolaldehyde.

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A Multi-Ringed, Modestly-Inclined Protoplanetary Disk around AA Tau

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AA Tau is the archetype for a class of stars with a peculiar periodic photometric variability thought to be related to a warped inner disk structure with a nearly edge-on viewing geometry. We present high resolution ($\sim0''.2$) ALMA observations of the 0.87 and 1.3 mm dust continuum emission from the disk around AA Tau. These data reveal an evenly spaced three-ringed emission structure, with distinct peaks at $0''.34$, $0''.66$, and $0''.99$, all viewed at a modest inclination of $59^\circ.1\pm0^\circ.3$ (decidedly not edge-on). In addition to this ringed substructure, we find non-axisymmetric features including a 'bridge' of emission that connects opposite sides of the innermost ring. We speculate on the nature of this 'bridge' in light of accompanying observations of HCO^+ and ^{13}CO (J=3–2) line emission. The HCO^+ emission is bright interior to the innermost dust ring, with a projected velocity field that appears rotated with respect to the resolved disk geometry, indicating the presence of a warp or inward radial flow. We suggest that the continuum bridge and HCO^+ line kinematics could originate from gap-crossing accretion streams, which may be responsible for the long-duration dimming of optical light from AA Tau.

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X-Shooter study of accretion in Chamaeleon I: II. A steeper increase of accretion with stellar mass for very low mass stars?

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The dependence of the mass accretion rate on the stellar properties is a key constraint for star formation and disk evolution studies. Here we present a study of a sample of stars in the Chamaeleon I star forming region carried out using spectra taken with the ESO VLT/X-Shooter spectrograph. The sample is nearly complete down to stellar masses $(M_\star) \sim 0.1 M_\odot$ for the young stars still harboring a disk in this region. We derive the stellar and accretion parameters using a self-consistent method to fit the broad-band flux-calibrated medium resolution spectrum. The correlation between the accretion luminosity to the stellar luminosity, and of the mass accretion rate to the stellar mass in the logarithmic plane yields slopes of 1.9±0.1 and 2.3±0.3, respectively. These slopes and the accretion rates are consistent with previous results in various star forming regions and with different theoretical frameworks. However, we find that a broken power-law fit, with a steeper slope for stellar luminosity smaller than $\sim 0.45\ L_\odot$ and for stellar masses smaller than $\sim 0.3\ M_\odot$, is slightly preferred according to different statistical tests, but the single power-law model is not excluded. The steeper relation for lower mass stars can be interpreted as a faster evolution in the past for accretion in disks around these objects, or as different accretion regimes in different stellar mass ranges. Finally, we find two regions on the mass accretion versus stellar mass plane empty of objects. One at high mass accretion rates and low stellar masses, which is related to the steeper dependence of the two parameters we derived. The second one is just above the observational limits imposed by chromospheric emission. This empty region is located at $M_\star \sim 0.3 - 0.4 M_\odot$, typical masses where photoevaporation is known to be effective, and at mass accretion rates $\sim 10^{?10} M_\odot$/yr, a value compatible with the one expected for photoevaporation to rapidly dissipate the inner disk.

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The ALMA view of W33A: a spiral filament feeding the candidate disc in MM1-Main

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We targeted the massive star-forming region W33A using the Atacama large sub/millimeter array in bands 6 (230 GHz) and 7 (345 GHz) to search for a sub-1000 au disc around the central O-type massive young stellar object W33A MM1-Main. Our data achieve a resolution of ∼0.2 arcsec (∼500 au) and resolve the central core, MM1, into multiple components and reveal complex and filamentary structures. There is strong molecular line emission covering the entire MM1 region. The kinematic signatures are inconsistent with only Keplerian rotation although we propose that the shift in the emission line centroids within ∼1000 au of MM1-Main could hint at an underlying compact disc with Keplerian rotation. We cannot however rule out the possibility of an unresolved binary or multiple system. A putative smaller disc could be fed by the large-scale spiral feeding filament we detect in both gas and dust emission. We also discuss the nature of the now-resolved continuum sources.

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An Estimation of the Star Formation Rate in the Perseus Complex

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We present the results of our investigation of the star-forming potential in the Perseus star-forming complex. We build on previous starless core, protostellar core, and young stellar object (YSO) catalogs from Spitzer (3.670 ?m), Herschel (70500 ?m), and SCUBA (850 ?m) observations in the literature. We place the cores and YSOs within seven star-forming clumps based on column densities greater than 5×10^{21} cm^{-2}. We calculate the mean density and free-fall time for 69 starless cores as $\sim$5.55 $\times 10^{-19}$ g cm^{-3} and $\sim$0.1 Myr, respectively, and we estimate the star formation rate for the near future as $\sim$150 $M_{\odot}$Myr^{-1}. According to Bonnor-Ebert stability analysis, we find that majority of starless cores in Perseus are unstable. Broadly, these cores can collapse to form the next generation of stars. We found a relation between starless cores and YSOs, where the numbers of young protostars (Class 0 + Class I) are similar to the numbers of starless cores. This similarity, which shows a one-to-one relation, suggests that these starless cores may form the next generation of stars with approximately the same formation rate as the current generation, as identified by the Class 0 and Class I protostars. It follows that if such a relation between starless core and any YSO stage exists, SFR values of these two populations must be nearly constant. In brief, we propose that this one-to-one relation is an important factor in better understanding the star formation process within a cloud.

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On the Origin of the Spiral Morphology in the Elias 2–27 Circumstellar Disk

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The young star Elias 2–27 has recently been observed to posses a massive circumstellar disk with two prominent large-scale spiral arms. In this Letter, we perform three-dimensional Smoothed Particle Hydrodynamics simulations, radiative transfer modeling, synthetic ALMA imaging, and an unsharped masking technique to explore three possibilities for the origin of the observed structures — an undetected companion either internal or external to the spirals, and a self-gravitating disk. We find that a gravitationally unstable disk and a disk with an external companion can produce morphology that is consistent with the observations. In addition, for the latter, we find that the companion could be a relatively massive planetary-mass companion ($\lesssim 10 - 13 M_{\rm Jup}$) and located at large radial distances (between $\approx 300 - 700$ au). We therefore suggest that Elias 2–27 may be one of the first detections of a disk undergoing gravitational instabilities, or a disk that has recently undergone fragmentation to produce a massive companion.

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EXors and the Stellar Birthline

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We assess the evolutionary status of EXors. These low-mass, pre-main-sequence stars repeatedly undergo sharp luminosity increases, each a year or so in duration. We place into the HR diagram all EXors that have documented quiescent luminosities and effective temperatures, and thus determine their masses and ages. Two alternate sets of

pre-main-sequence tracks are used, and yield similar results. Roughly half of EXors are embedded objects, i.e., they appear observationally as Class I or flat-spectrum infrared sources. We find that these are relatively young and are located close to the stellar birthline in the HR diagram. Optically visible EXors, on the other hand, are situated well below the birthline. They have ages of several Myr, typical of classical T Tauri stars. Judging from the limited data at hand, we find no evidence that binarity companions trigger EXor eruptions; this issue merits further investigation. We draw several general conclusions. First, repetitive luminosity outbursts do not occur in all pre-main-sequence stars, and are not in themselves a sign of extreme youth. They persist, along with other signs of activity, in a relatively small subset of these objects. Second, the very existence of embedded EXors demonstrates that at least some Class I infrared sources are not true protostars, but very young pre-main-sequence objects still enshrouded in dusty gas. Finally, we believe that the embedded pre-main-sequence phase is of observational and theoretical significance, and should be included in a more complete account of early stellar evolution.

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H_2CO distribution and formation in the TW Hya disk

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H_2CO is one of the most readily detected organic molecules in protoplanetary disks. Yet its distribution and dominant formation pathway(s) remain largely unconstrained. To address these issues, we present ALMA observations of two H_2CO lines ($3_{12} - 2_{11}$ and $5_{15} - 4_{14}$) at 0.5" (∼30 au) spatial resolution toward the disk around the nearby T Tauri star TW Hya. Emission from both lines is spatially resolved, showing a central depression, a peak at 0.4" radius, and a radial decline at larger radii with a bump at $\sim 1''$, near the millimeter continuum edge. We adopt a physical model for the disk and use toy models to explore the radial and vertical H_2CO abundance structure. We find that the observed emission implies the presence of at least two distinct H_2CO gas reservoirs: (1) a warm and unresolved inner component (< 10 au), and (2) an outer component that extends from ~ 15 au to beyond the millimeter continuum edge. The outer component is further constrained by the line ratio to arise in a more elevated disk layer at larger radii. The inferred H_2CO abundance structure agrees well with disk chemistry models, which predict efficient H_2CO gas-phase formation close to the star, and cold H_2CO grain surface formation, through H additions to condensed CO, followed by non-thermal desorption in the outer disk. The implied presence of active grain surface chemistry in the TW Hya disk is consistent with the recent detection of CH_3OH emission, and suggests that more complex organic molecules are formed in disks, as well.

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What sets the massive star formation rates and efficiencies of giant molecular clouds?

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Galactic star formation scaling relations show increased scatter from kpc to sub-kpc scales. Investigating this scatter may hold important clues to how the star formation process evolves in time and space. Here, we combine different

molecular gas tracers, different star formation indicators probing distinct populations of massive stars, and knowledge on the evolutionary state of each star forming region to derive star formation properties of ~ 150 star forming complexes over the face of the Large Magellanic Cloud. We find that the rate of massive star formation ramps up when stellar clusters emerge and boost the formation of subsequent generations of massive stars. In addition, we reveal that the star formation efficiency of individual GMCs declines with increasing cloud gas mass ($M_{\rm cloud}$). This trend persists in Galactic star forming regions, and implies higher molecular gas depletion times for larger GMCs.
We compare the star formation efficiency per freefall time ($\epsilon_{\rm ff}$) with predictions from various widely-used analytical star formation models. We show that while these models can produce large dispersions in $\epsilon_{\rm ff}$ similar to observations, the origin of the model-predicted scatter is inconsistent with observations. Moreover, all models fail to reproduce the observed decline of $\epsilon_{\rm ff}$ with increasing $M_{\rm cloud}$ in the LMC and the Milky Way. We conclude that analytical star formation models idealizing global turbulence levels, cloud densities, and assuming a stationary SFR are inconsistent with observations from modern datasets tracing massive star formation on individual cloud scales. Instead, we reiterate the importance of local stellar feedback in shaping the properties of GMCs and setting their massive star formation rate.

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Silicon-bearing molecules in the shock L1157-B1: first detection of SiS around a Sun-like protostar

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The shock L1157-B1 driven by the low-mass protostar L1157-mm is an unique environment to investigate the chemical enrichment due to molecules released from dust grains. IRAM-30m and Plateau de Bure Interferometer observations allow a census of Si-bearing molecules in L1157-B1. We detect SiO and its isotopologues and, for the first time in a shock, SiS. The strong gradient of the [SiO/SiS] abundance ratio across the shock (from ≥ 180 to ~ 25) points to a different chemical origin of the two species. SiO peaks where the jet impacts the cavity walls ([SiO/H_2]$\sim 10^{-6}$), indicating that SiO is directly released from grains or rapidly formed from released Si in the strong shock occurring at this location. In contrast, SiS is only detected at the head of the cavity opened by previous ejection events ([SiS/H_2]$\sim 2 \times 10^{-8}$). This suggests that SiS is not directly released from the grain cores but instead should be formed through slow gas-phase processes using part of the released silicon. This finding shows that Si-bearing molecules can be useful to distinguish regions where grains or gas-phase chemistry dominates.

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First large scale Herbig-Haro jet driven by a proto-brown dwarf

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We report the discovery of a new Herbig-Haro jet, HH 1165, in SOAR narrow-band imaging of the vicinity of the σ Orionis cluster. HH 1165 shows a spectacular extended and collimated spatial structure, with a projected length of 0.26 pc, a bent **C**-shaped morphology, multiple knots, and fragmented bow-shocks at the apparent ends of the flow. The Hα image shows a bright halo with a clumpy distribution of material seen around the driving source, and curved reflection nebulosity tracing the outflow cavities. The driving source of HH 1165 is a Class I proto-brown dwarf, Mayrit 1701117 (M1701117), with a total (dust+gas) mass of $\sim$36 M_{Jup} and a bolometric luminosity of $\sim$0.1 $L_\odot$. High-resolution VLT/UVES spectra of M1701117 show a wealth of emission lines indicative of strong outflow and accretion activity. SOAR/Goodman low-resolution spectra along the jet axis show an asymmetrical morphology for HH 1165. We find a puzzling picture wherein the north-west part exhibits a classical HH jet running into a predominantly neutral medium, while the southern part resembles an externally irradiated jet. The **C**-shaped bending in HH 1165 may be produced by the combined effects from the massive stars in the ionization front to the east, the σ Orionis core to the west, and the close proximity to the B2-type star HR 1950. HH 1165 shows all of the signatures to be considered as a scaled-down version of parsec-length HH jets, and can be termed as the first sub-stellar analog of a protostellar HH jet system.

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Embedded Binaries and Their Dense Cores

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We explore the relationship between young, embedded binaries and their parent cores, using observations within the Perseus Molecular Cloud. We combine recently published VLA observations of young stars with core properties obtained from SCUBA-2 observations at 850 um. Most embedded binary systems are found toward the centres of their parent cores, although several systems have components closer to the core edge. Wide binaries, defined as those systems with physical separations greater than 500 au, show a tendency to be aligned with the long axes of their parent cores, whereas tight binaries show no preferred orientation. We test a number of simple, evolutionary models to account for the observed populations of Class 0 and I sources, both single and binary. In the model that best explains the observations, all stars form initially as wide binaries. These binaries either break up into separate stars or else shrink into tighter orbits. Under the assumption that both stars remain embedded following binary breakup, we find a total star formation rate of 168 Myr^{-1}. Alternatively, one star may be ejected from the dense core due to binary breakup. This latter assumption results in a star formation rate of 247 Myr^{-1}. Both production rates are in satisfactory agreement with current estimates from other studies of Perseus. Future observations should be able to distinguish between these two possibilities. If our model continues to provide a good fit to other star-forming regions, then the mass fraction of dense cores that becomes stars is double what is currently believed.

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Planar infall of CH_3OH gas around Cepheus A HW2

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Aims: In order to test the nature of an (accretion) disk in the vicinity of Cepheus A HW2, we measured the three-dimensional velocity field of the CH_3OH maser spots, which are projected within 1000 au of the HW2 object, with an accuracy of the order of $0.1\,km\,s^{-1}$. *Methods:* We made use of the European VLBI Network (EVN) to image the 6.7 GHz CH_3OH maser emission towards Cepheus A HW2 with 4.5 milli-arcsecond resolution (3 au). We observed at three epochs spaced by one year between 2013 and 2015. During the last epoch, on mid-march 2015, we benefited from the new deployed Sardinia Radio Telescope. *Results:* We show that the CH_3OH velocity vectors lie on a preferential plane for the gas motion with only small deviations of $12^\circ \pm 9^\circ$ away from the plane. This plane is oriented at a position angle of 134° east of north, and inclined by 26° with the line-of-sight, closely matching the orientation of the disk-like structure previously reported by Patel et al. (2005). Knowing the orientation of the equatorial plane, we can reconstruct a face-on view of the CH_3OH gas kinematics onto the plane. CH_3OH maser emission is detected within a radius of 900 au from HW2, and down to a radius of about 300 au, the latter coincident with the extent of the dust emission at 0.9 mm. The velocity field is dominated by an infall component of about $2\,km\,s^{-1}$ down to a radius of 300 au, where a rotational component of $4\,km\,s^{-1}$ becomes dominant. We discuss the nature of this velocity field and the implications for the enclosed mass. *Conclusions:* These findings bring direct support to the interpretation that the high-density gas and dust emission, surrounding Cepheus A HW2, trace an accretion disk.

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WL 17: A Young Embedded Transition Disk

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We present the highest spatial resolution ALMA observations to date of the Class I protostar WL 17 in the ρ Ophiuchus L1688 molecular cloud complex, which show that it has a 12 AU hole in the center of its disk. We consider whether WL 17 is actually a Class II disk being extincted by foreground material, but find that such models do not provide a good fit to the broadband SED and also require such high extinction that it would presumably arise from dense material close to the source such as a remnant envelope. Self-consistent models of a disk embedded in a rotating collapsing envelope can nicely reproduce both the ALMA 3 mm observations and the broadband SED of WL 17. This suggests that WL 17 is a disk in the early stages of its formation, and yet even at this young age the inner disk has been depleted. Although there are multiple pathways for such a hole to be created in a disk, if this hole were produced by the formation of planets it could place constraints on the timescale for the growth of planetesimals in protoplanetary disks.

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Testing the universality of the star formation efficiency in dense molecular gas

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Recent studies with, e.g., *Spitzer* and *Herschel* have suggested that star formation in dense molecular gas may be governed by essentially the same "law" in Galactic clouds and external galaxies. This conclusion remains controversial, however, in large part because different tracers have been used to probe the mass of dense molecular gas in Galactic and extragalactic studies.
We aimed to calibrate the HCN and HCO^+ lines commonly used as dense gas tracers in extragalactic studies and to test the possible universality of the star formation efficiency in dense gas ($\gtrsim 10^4$ cm^{-3}), $\mathrm{SFE_{dense}}$.
We conducted wide-field mapping of the Aquila, Ophiuchus, and Orion B clouds at ~0.04 pc resolution in the J=1–0 transition of HCN, HCO^+, and their isotopomers. For each cloud, we derived a reference estimate of the dense gas mass $M^{A_V>8}_{\mathrm{Herschel}}$, as well as the strength of the local far-ultraviolet (FUV) radiation field, using *Herschel* Gould Belt survey data products, and estimated the star formation rate from direct counting of the number of *Spitzer* young stellar objects.
The $H^{13}CO^+$(1–0) and $H^{13}CN$(1–0) lines were observed to be good tracers of the dense star-forming filaments detected with *Herschel*. Comparing the luminosities L_{HCN} and $L_{\mathrm{HCO^+}}$ measured in the HCN and HCO^+ lines with the reference masses $M^{A_V>8}_{\mathrm{Herschel}}$, the empirical conversion factors $\alpha_{\mathrm{Herschel-HCN}}$ ($= M^{A_V>8}_{\mathrm{Herschel}}/L_{\mathrm{HCN}}$) and $\alpha_{\mathrm{Herschel-HCO^+}}$ ($= M^{A_V>8}_{\mathrm{Herschel}}/L_{\mathrm{HCO^+}}$) were found to be significantly anti-correlated with the local FUV strength. In agreement with Pety et al. (2016), the HCN and HCO^+ lines were also found to trace gas down to $A_V \gtrsim 2$. As a result, published extragalactic HCN studies must be tracing all of the moderate density gas down to $n_{H_2} \lesssim 10^3\,\mathrm{cm^{-3}}$. Estimating the contribution of this moderate density gas from the typical column density PDFs in nearby clouds, we obtained the following G_0-dependent HCN conversion factor for external galaxies: $\alpha^{\mathrm{fit}'}_{\mathrm{Herschel-HCN}} = 64 \times G_0^{-0.34}$. Re-estimating the dense gas masses in external galaxies with $\alpha^{\mathrm{fit}'}_{\mathrm{Herschel-HCN}}(G_0)$, we found that $\mathrm{SFE_{dense}}$ is remarkably constant, with a scatter of less than 1.5 orders of magnitude around $4.5 \times 10^{-8}\,\mathrm{yr^{-1}}$, over 8 orders of magnitude in dense gas mass.
Our results confirm that $\mathrm{SFE_{dense}}$ of galaxies is quasi-universal on a wide range of scales from $\sim$ 1–10 pc to $>$ 10 kpc. Based on the tight link between star formation and filamentary structure found in *Herschel* studies of nearby clouds, we argue that $\mathrm{SFE_{dense}}$ is primarily set by the "microphysics" of core/star formation along filaments.

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Coevality in Young Eclipsing Binaries

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The ages of the components in very short period pre-main sequence (PMS) binaries are essential to an understanding of their formation. We considered a sample of 7 PMS eclipsing binaries (EBs) with ages 1 to 6.3 MY and component masses 0.2 to 1.4 Msun. The very high precision with which their masses and radii have been measured, and the capability provided by the Modules for Experiments in Stellar Astrophysics (MESA) to calculate their evolutionary tracks at exactly the measured masses, allows the determination of age differences of the components independent of their luminosities and effective temperatures. We found that the components of 5 EBs, ASAS J052821+0338.5, Parenago 1802, JW 380, CoRoT 223992193, & UScoCTIO 5, formed within 0.3 MY of each other. The parameters for the components of V1174 Ori, imply an implausible large age difference of 2.7 MY and should be reconsidered. The 7th EB in our sample, RX J0529.4+0041 fell outside the applicability of our analysis.

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New Low-Mass Stars in the 25 Orionis Stellar Group and Orion OB1a Sub-association from SDSS-III/BOSS Spectroscopy

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The Orion OB1a sub-association is a rich low mass star (LMS) region. Previous spectroscopic studies have confirmed 160 LMSs in the 25 Orionis stellar group (25 Ori), which is the most prominent overdensity of Orion OB1a. Nonetheless, the current census of the 25 Ori members is estimated to be less than 50% complete, leaving a large number of members to be still confirmed. We retrieved 172 low-resolution stellar spectra in Orion OB1a observed as ancillary science in the SDSS-III/BOSS survey, for which we classified their spectral types and determined physical parameters. To determine memberships, we analyzed the H_α emission, LiIλ6708 absorption, and NaI$\lambda\lambda$8183, 8195 absorption as youth indicators in stars classified as M-type. We report 50 new LMSs spread across the 25 Orionis, ASCC 18, and ASCC 20 stellar groups with spectral types from M0 to M6, corresponding to a mass range of $0.10 \leq m/M_\odot \leq 0.58$. This represents an increase of 50% in the number of known LMSs in the area and a net increase of 20% in the number of 25 Ori members in this mass range. Using parallax values from the Gaia DR1 catalog, we estimated the distances to these three stellar groups and found that they are all co-distant, at 338±66 pc. We analyzed the spectral energy distributions of these LMSs and classified their disks by evolutionary classes. Using H-R diagrams, we found a suggestion that 25 Ori could be slightly older that the other two observed groups in Orion OB1a.

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An Optical and Infrared Photometric Study of the Young Open Cluster IC 1805 in the Giant H II Region W4

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We present deep wide-field optical CCD photometry and mid-infrared Spitzer/IRAC and MIPS 24micron data for about 100,000 stars in the young open cluster IC 1805. The members of IC 1805 were selected from their location in the various color-color and color-magnitude diagrams, and the presence of Hα emission, mid-infrared excess emission, and X-ray emission. The reddening law toward IC 1805 is nearly normal ($R_V = 3.05 \pm 0.06$). However, the distance modulus of the cluster is estimated to be 11.9±0.2 mag ($d = 2.4 \pm 0.2$ kpc) from the reddening-free color-magnitude diagrams, which is larger than the distance to the nearby massive star-forming region W3(OH) measured from the radio VLBA astrometry. We also determined the age of IC 1805 ($\tau_{\rm MSTO} = 3.5$ Myr). In addition, we critically compared the age and mass scale from two pre-main-sequence evolution models. The initial mass function with a Salpeter-type slope of $\Gamma = -1.3 \pm 0.2$ was obtained and the total mass of IC 1805 was estimated to be about 2700±200 $M_\odot$. Finally, we found our distance determination to be statistically consistent with the Tycho-Gaia Astrometric Solution Data Release 1, within the errors. The proper motion of the B-type stars shows an elongated distribution along the Galactic plane, which could be explained by some of the B-type stars being formed in small clouds dispersed by previous episodes of star formation or supernova explosions.

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Kinetic temperature of massive star forming molecular clumps measured with formaldehyde

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For a general understanding of the physics involved in the star formation process, measurements of physical parameters such as temperature and density are indispensable. The chemical and physical properties of dense clumps of molecular clouds are strongly affected by the kinetic temperature. Therefore, this parameter is essential for a better understanding of the interstellar medium. Formaldehyde, a molecule which traces the entire dense molecular gas, appears to be the most reliable tracer to directly measure the gas kinetic temperature. We aim to determine the kinetic temperature with spectral lines from formaldehyde and to compare the results with those obtained from ammonia lines for a large number of massive clumps. Three 218 GHz transitions ($J_{\rm K_A K_C}$ = 3_{03}-2_{02}, 3_{22}-2_{21}, and 3_{21}-2_{20}) of para-H_2CO were observed with the 15m James Clerk Maxwell Telescope (JCMT) toward 30 massive clumps of the Galactic disk at various stages of high-mass star formation. Using the RADEX non-LTE model, we derive the gas kinetic temperature modeling the measured para-H_2CO 3_{22}-2_{21}/3_{03}-2_{02} and 3_{21}-2_{20}/3_{03}-2_{02} ratios. The gas kinetic temperatures derived from the para-H_2CO (3_{21}-2_{20}/3_{03}-2_{02}) line ratios range from 30 to 61 K with an average of 46 $\pm$ 9 K. A comparison of kinetic temperature derived from para-H_2CO, NH_3, and the dust emission indicates that in many cases para-H_2CO traces a similar kinetic temperature to the NH_3 (2,2)/(1,1) transitions and the dust associated with the HII regions. Distinctly higher temperatures are probed by para-H_2CO in the clumps associated with outflows/shocks. Kinetic temperatures obtained from para-H_2CO trace turbulence to a higher degree than NH_3 (2,2)/(1,1) in the massive clumps. The non-thermal velocity dispersions of para-H_2CO lines are positively correlated with the gas kinetic temperature. The massive clumps are significantly influenced by supersonic non-thermal motions.

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Kinetic temperature of massive star-forming molecular clumps measured with formaldehyde. II. The Large Magellanic Cloud

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The kinetic temperature of molecular clouds is a fundamental physical parameter affecting star formation and the initial mass function. The Large Magellanic Cloud (LMC) is the closest star-forming galaxy with a low metallicity and provides an ideal laboratory for studying star formation in such an environment. The classical dense molecular gas thermometer NH_3 is seldom available in a low-metallicity environment because of photoionization and a lack of nitrogen atoms. Our goal is to directly measure the gas kinetic temperature with formaldehyde toward six star-forming regions in the LMC. Three rotational transitions ($J_{\mathrm{K_AK_C}} = 3_{03}$-$2_{02}$, 3_{22}-2_{21}, and 3_{21}-2_{20}) of para-H_2CO near 218 GHz were observed with the Atacama Pathfinder EXperiment (APEX) 12 m telescope toward six star-forming regions in the LMC. These data are complemented by $C^{18}O$ 2-1 spectra. Using non-local thermal equilibrium modeling with RADEX, we derive the gas kinetic temperature and spatial density, using as constraints the measured para-H_2CO 3_{21}-2_{20}/3_{03}-2_{02} and para-H_2CO 3_{03}-2_{02}/$C^{18}O$ 2-1 ratios. Excluding the quiescent cloud N159S, where only one para-H_2CO line could be detected, the gas kinetic temperatures derived from the preferred para-H_2CO 3_{21}-2_{20}/3_{03}-2_{02} line ratios range from 35 to 63 K with an average of 47 ± 5 K (errors are unweighted standard deviations of the mean). Spatial densities of the gas derived from the para-H_2CO 3_{03}-2_{02}/$C^{18}O$ 2-1 line ratios yield $0.4 - 2.9 \times 10^5$ $\mathrm{cm^{-3}}$ with an average of $1.5 \pm 0.4 \times 10^5$ $\mathrm{cm^{-3}}$. Temperatures derived from the para-H_2CO line ratio are similar to those obtained with the same method from Galactic star-forming regions and agree with results derived from CO in the dense regions ($n(H_2) > 10^3$ $\mathrm{cm^{-3}}$) of the LMC. A comparison of kinetic temperatures derived from para-H_2CO with those from the dust also shows good agreement. This suggests that the dust and para-H_2CO are well mixed in the studied star-forming regions. A comparison of kinetic temperatures derived from para-H_2CO 3_{21}-2_{20}/3_{03}-2_{02} and NH_3(2,2)/(1,1) shows a drastic difference, however. In the star-forming region N159W, the gas temperature derived from the NH_3(2,2)/(1,1) line ratio is ∼16 K (Ott et al. 2010), which is only half the temperature derived from para-H_2CO and the dust. Furthermore, ammonia shows a very low abundance in a 30″ beam. Apparently, ammonia only survives in the most shielded pockets of dense gas that are not yet irradiated by UV photons, while formaldehyde, less affected by photodissociation, is more widespread and also samples regions that are more exposed to the radiation of young massive stars. A correlation between the gas kinetic temperatures derived from para-H_2CO and infrared luminosity, represented by the 250 μm flux, suggests that the kinetic temperatures traced by para-H_2CO are correlated with the ongoing massive star formation in the LMC.

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Circumbinary disks: Numerical and physical behaviour

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We study the evolution of circumbinary disks under the gravitational influence of the binary using two-dimensional hydrodynamical simulations to investigate the impact of disk and binary parameters on the dynamical aspects of the disk. To distinguish between physical and numerical effects we apply three hydrodynamical codes. First we analyse in detail numerical issues concerning the conditions at the boundaries and grid resolution. We then perform a series of simulations with different binary (eccentricity, mass ratio) and disk parameters (viscosity, aspect ratio) starting from a reference model with Kepler-16 parameters.

Concerning the numerical aspects we find that the inner grid radius must be of the order of the binary semi-major axis, with free outflow conditions applied such that mass can flow onto the central binary. A closed inner boundary leads to unstable evolutions.

We find that the inner disk turns eccentric and precesses for all investigated physical parameters. The precession rate is slow with periods (T_{prec}) starting at around 500 binary orbits (T_{bin}) for high viscosity and large H/R where the inner hole is smaller and more circular. Reducing α and H/R increases the gap size and T_{prec} reaches 2500 T_{bin}. For varying binary mass ratios q_{bin} the gap size remains constant whereas T_{prec} decreases for increasing q_{bin}.

For varying binary eccentricities e_{bin} we find two separate branches in the gap size and eccentricity diagram. The bifurcation occurs at around $e_{\mathrm{crit}} \approx 0.18$ where the gap is smallest with the shortest T_{prec}. For e_{bin} smaller and larger than e_{crit} the gap size and T_{prec} increase. Circular binaries create the most eccentric disks.

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Mid-infrared interferometric variability of DG Tau: implications for the inner-disk structure

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Context. DG Tau is a low-mass pre-main sequence star, whose strongly accreting protoplanetary disk exhibits a so-far enigmatic behavior: its mid-infrared thermal emission is strongly time-variable, even turning the 10 μm silicate feature from emission to absorption temporarily.
Aims. We look for the reason for the spectral variability at high spatial resolution and at multiple epochs.
Methods. Infrared interferometry can spatially resolve the thermal emission of the circumstellar disk, also giving information about dust processing. We study the temporal variability of the mid-infrared interferometric signal, observed with the VLTI/MIDI instrument at six epochs between 2011 and 2014. We fit a geometric disk model to the observed interferometric signal to obtain spatial information about the disk. We also model the mid-infrared spectra by template fitting to characterize the profile and time dependence of the silicate emission. We use physically motivated radiative transfer modeling to interpret the mid-infrared interferometric spectra.
Results. The inner disk ($r < 1-3\,$au) spectra exhibit a 10 μm absorption feature related to amorphous silicate grains. The outer disk ($r > 1-3\,$au) spectra show a crystalline silicate feature in emission, similar to the spectra of comet Hale-Bopp. The striking difference between the inner and outer disk spectral feature is highly unusual among T Tauri stars. The mid-infrared variability is dominated by the outer disk. The strength of the silicate feature changed by more than a factor of two. Between 2011 and 2014 the half-light radius of the mid-infrared-emitting region decreased from 1.15 to 0.7 au.
Conclusions. For the origin of the absorption we discuss four possible explanations: a cold obscuring envelope, an accretion heated inner disk, a temperature inversion on the disk surface and a misaligned inner geometry. The silicate emission in the outer disk can be explained by dusty material high above the disk plane, whose mass can change with time, possibly due to turbulence in the disk.

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First results from BISTRO – a SCUBA-2 polarimeter survey of the Gould Belt

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We present the first results from the B-fields In STar-forming Region Observations (BISTRO) survey, using the Submillimetre Common-User Bolometer Array 2 (SCUBA-2) camera, with its associated polarimeter (POL-2), on the James Clerk Maxwell Telescope (JCMT) in Hawaii. We discuss the survey's aims and objectives. We describe the rationale behind the survey, and the questions which the survey will aim to answer. The most important of these is the role of magnetic fields in the star formation process on the scale of individual filaments and cores in dense regions. We describe the data acquisition and reduction processes for POL-2, demonstrating both repeatability and consistency with previous data. We present a first-look analysis of the first results from the BISTRO survey in the OMC 1 region. We see that the magnetic field lies approximately perpendicular to the famous 'integral filament' in the densest regions of that filament. Furthermore, we see an 'hour-glass' magnetic field morphology extending beyond the densest region of the integral filament into the less-dense surrounding material, and discuss possible causes for this. We also discuss the more complex morphology seen along the Orion Bar region. We examine the morphology of the field along the lower-density north-eastern filament. We find consistency with previous theoretical models that predict magnetic fields lying parallel to low-density, non-self-gravitating filaments, and perpendicular to higher-density, self-gravitating filaments.

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GMC Collisions as Triggers of Star Formation. III. Density and Magnetically Regulated Star Formation

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We study giant molecular cloud (GMC) collisions and their ability to trigger star cluster formation. We further develop our three dimensional magnetized, turbulent, colliding GMC simulations by implementing star formation subgrid models. Two such models are explored: (1) "Density-Regulated," i.e., fixed efficiency per free-fall time above a set density threshold; (2) "Magnetically- Regulated," i.e., fixed efficiency per free-fall time in regions that are magnetically supercritical. Variations of parameters associated with these models are also explored. In the non-colliding simulations, the overall level of star formation is sensitive to model parameter choices that relate to effective density thresholds. In the GMC collision simulations, the final star formation rates and efficiencies are relatively independent of these parameters. Between non-colliding and colliding cases, we compare the morphologies of the resulting star clusters, properties of star-forming gas, time evolution of the star formation rate (SFR), spatial clustering of the stars, and resulting kinematics of the stars in comparison to the natal gas. We find that typical collisions, by creating larger amounts of dense gas, trigger earlier and enhanced star formation, resulting in 10 times higher SFRs and efficiencies. The star clusters formed from GMC collisions show greater spatial sub-structure and more disturbed kinematics.

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High-mass Starless Clumps in the inner Galactic Plane: the Sample and Dust Properties

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We report a sample of 463 high-mass starless clump (HMSC) candidates within $-60° < l < 60°$ and $-1° < b < 1°$. This sample has been singled out from 10861 ATLASGAL clumps. All of these sources are not associated with any known star-forming activities collected in SIMBAD and young stellar objects identified using color-based criteria. We also make sure that the HMSC candidates have neither point sources at 24 and 70 μm nor strong extended emission at 24 μm. Most of the identified HMSCs are infrared ($\leq$ 24 μm) dark and some are even dark at 70 μm. Their distribution shows crowding in Galactic spiral arms and toward the Galactic center and some well-known star-forming complexes. Many HMSCs are associated with large-scale filaments. Some basic parameters were attained from column density and dust temperature maps constructed via fitting far-infrared and submillimeter continuum data to modified blackbodies. The HMSC candidates have sizes, masses, and densities similar to clumps associated with Class II methanol masers and HII regions, suggesting they will evolve into star-forming clumps. More than 90% of the HMSC candidates have densities above some proposed thresholds for forming high-mass stars. With dust temperatures and luminosity-to-mass ratios significantly lower than that for star-forming sources, the HMSC candidates are externally heated and genuinely at very early stages of high-mass star formation. Twenty sources with equivalent radius $r_{\rm eq} < 0.15$ pc and mass surface density $\Sigma > 0.08$ g cm^{-2} could be possible high-mass starless cores. Further investigations toward these HMSCs would undoubtedly shed light on comprehensively understanding the birth of high-mass stars.

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Abstracts of recently accepted major reviews

Multiwavelength Studies of Young OB Associations

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We discuss how contemporary multiwavelength observations of young OB-dominated clusters address long-standing astrophysical questions: Do clusters form rapidly or slowly with an age spread? When do clusters expand and disperse to constitute the field star population? Do rich clusters form by amalgamation of smaller subclusters? What is the pattern and duration of cluster formation in massive star forming regions (MSFRs)? Past observational difficulties in obtaining good stellar censuses of MSFRs have been alleviated in recent studies that combine X-ray and infrared surveys to obtain rich, though still incomplete, censuses of young stars in MSFRs. We describe here one of these efforts, the MYStIX project, that produced a catalog of 31,784 probable members of 20 MSFRs. We find that age spread within clusters are real in the sense that the stars in the core formed after the cluster halo. Cluster expansion is seen in the ensemble of (sub)clusters, and older dispersing populations are found across MSFRs. Direct evidence for subcluster merging is still unconvincing. Long-lived, asynchronous star formation is pervasive across MSFRs.

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http://arxiv.org/pdf/1704.08115

New Jobs

Postdoc position in planet formation

Lund University invites applicants to a postdoc position in planet formation.

The successful applicant will work within the PLANETESYS project that was recently funded by the European Research Council (PI: Anders Johansen). The overarching goal of the project is the development and exploitation of an N-body code to simulate the formation of planets, including growth by accretion of pebbles, planetesimals and gas. The project also concerns the chemical composition of planets and the delivery of life-essential molecules to habitable planets.

Researchers with an experience background in any area of theoretical or computational astrophysics or astrochemistry are invited to apply.

The position is initially time-limited to two years, but can be extended to three or four years, based on work progress.

Part of the research can consist of own, independent projects. Please contact Anders Johansen (anders@astro.lu.se) for details.

Link to job announcement at http://www.astro.lu.se/vacancies/

Second announcement:

Ages^2: Taking stellar ages to the next power

September 18-22, 2017 – Elba, Italy

Program and deadlines web page: http://www.stsci.edu/institute/conference/ages2017
registration and local information web page: http://agenda.infn.it/event/StellarAges2017

This is the second announcement for a symposium on stellar ages to be held this fall. 'The Ages of Stars' was held as IAU Symposium 258 in Baltimore in 2008. Much progress has been made since then in the critical problem of estimating stellar ages. This second Ages meeting will focus on these major themes:

1. Pre-main sequence and very young stars, and the connection to the formation and early evolution of stars and planetary systems.
2. Solar-type and low-mass stars, and the connection to exoplanets.
3. Evolved stars and the connection to Galactic archaeology.
4. High-mass and intermediate-mass stars and the connection to clusters.
5. Ages of the oldest stars and the connection to the halo and accretion.
6. Stellar models and their limitations.

We are planning an in-depth week covering a broad range of topics related to stellar ages.

Invited speakers:
A list of the current invited speakers can be found at: http://www.stsci.edu/institute/conference/ages2017

Contributed talks and poster abstracts:
Please go to http://agenda.infn.it/event/StellarAges2017 to submit an abstract.

Travel support:
A limited amount of travel support will be made available, especially for early career researchers. Please go to: http://agenda.infn.it/event/StellarAges2017.

For the SOC, the co-chairs:
David Soderblom, Space Telescope Science Institute – drs@stsci.edu
Scilla Degl'Innocenti, University of Pisa – scilla.deglinnocenti@unipi.it

Cloudy workshop at Queen's University Belfast
2017 July 21 to August 4

Registration is now open for the Cloudy workshop to be held 2017 July 21 to August 4 at Queens University, Belfast, Northern Ireland.

Cloudy is a large-scale code that simulates the microphysics of matter exposed to ionizing radiation. It calculates the atomic physics, chemistry, radiation transport, and dynamics problems simultaneously and self-consistently, building from a foundation of individual atomic and molecular processes. The result is a prediction of the conditions in the material and its observed spectrum.

The workshop will cover observation, theory, and application of Cloudy to a wide variety of astronomical environments. This includes the theory of diffuse matter and quantitative spectroscopy, the science of using spectra to make physical measurements. We will use Cloudy to simulate such objects as AGB stars, Active Galactic Nuclei, Starburst galaxies, and the intergalactic medium.

The sessions will consist of a mix of textbook study, using Osterbrock & Ferland, 'Astrophysics of Gaseous Nebulae and Active Galactic Nuclei', application of Cloudy to a variety of astrophysical problems, and projects organized by the participants. No prior experience with Cloudy is assumed although some knowledge of spectroscopy and the physics of the interstellar medium is useful.

See the website below for more information and for information on how to apply.

https://star.pst.qub.ac.uk/wiki/doku.php/public/cloudy2017

Summary of Upcoming Meetings

The migration issue: from protoplanets to supermassive black holes
22 - 24 May 2017, Cambridge, UK
http://www.ast.cam.ac.uk/meetings/2017/migration.issue.protoplanets.supermassive.black.holes

Protoplanetary Disks and Planet Formation and Evolution
29 May - 23 June 2017, Garching bei München, Germany
http://www.munich-iapp.de/scientific-programme/programmes-2017/protoplanetary-disks/

Accretion, Differentiation and Early Evolution of Terrestrial Planets
29 May - 3 June 2017, Nice, France
https://www-n.oca.eu/morby/Accrete.html

Francesco's Legacy: Star Formation in Space and Time
6 - 9 June 2017, Firenze, Italy
http://www.arcetri.astro.it/sfst2017/

Star Cluster Formation: Mapping the First Few Myr's
14 - 15 June 2017, Madrid, Spain
http://sfm.leeds.ac.uk/madrid-workshop-2017/

Gordon Research Seminar Origins of Solar Systems
17 - 18 June 2017, South Hadley, USA
https://www.grc.org/programs.aspx?id=17506

Gordon Research Conference Origins of Solar Systems: Making a Habitable Planet
18 - 23 June 2017, South Hadley, USA
https://www.grc.org/programs.aspx?id=12346

Comparing simulations and observations of the varying scales of star formation
26 - 27 June 2017, Prague, Czech Republic
http://eas.unige.ch/EWASS2017/session.jsp?id=S3

Galactic Star Formation with Surveys
3 - 7 July 2017, Heidelberg, Germany
http://www.mpia.de/homes/sc2017/index.html

Current and Future Perspectives of Chemical Modelling in Astrophysics
17 - 19 July 2017, Hamburg, Germany
http://www.hs.uni-hamburg.de/astromodel2017

Star Formation in Different Environments: From Local Clouds to Galaxies
6 - 12 August 2017, Quy Nhon, Vietnam
http://rencontresduvietnam.org/conferences/2017/sfde2017/

Ages^2: Taking stellar ages to the next power
18 - 22 September 2017, Elba, Italy
http://www.stsci.edu/institute/conference/ages2017

Planet Formation and Evolution 2017
25 - 27 September 2017, Jena, Germany
http://www.astro.uni-jena.de/~pfe2017

Short Announcements

Fizeau exchange visitors program - call for applications

Dear colleagues!

The Fizeau exchange visitors program in optical interferometry funds (travel and accommodation) visits of researchers to an institute of his/her choice (within the European Community) to perform collaborative work and training on one of the active topics of the European Interferometry Initiative. The visits will typically last for one month, and strengthen the network of astronomers engaged in technical, scientific and training work on optical/infrared interferometry. The program is open for all levels of astronomers (Ph.D. students to tenured staff), with priority given to PhD students and young postdocs. . non-EU based missions will only be funded if considered essential by the Fizeau Committee. Applicants are strongly encouraged to seek also partial support from their home or host institutions.

The deadline for applications is June 15. Fellowships can be awarded for missions to be carried out between August and November 2017!

Further informations and application forms can be found at `www.european-interferometry.eu`

The program is funded by OPTICON/H2020.

Please distribute this message also to potentially interested colleagues outside of your community!

Looking forward to your applications,
Josef Hron & Péter Ábrahám
(for the European Interferometry Initiative)

Email: fizeau@european-interferometry.eu

Moving ... ??

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