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

L1251 is a small cloud located at a distance of ∼300±50 pc, at the eastern edge of the Cepheus Flare. It is about 2 pc in diameter, and is active in low-mass star formation. The two principal embeddeds sources are the IRAS sources 22343+7501 and 22376+7455, both of which drive molecular outflows and Herbig-Haro flows. Infrared, radio continuum and X-ray surveys have revealed a small cluster of young T Tauri stars and embedded protostars towards the cloud. On larger scales the cloud has a cometary shape, and may suggest that it was shaped by a supernova bubble found nearby. The image is about 45×50 arcmin.

Image courtesy Fabian Neyer
http://www.starpointing.com

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

Elma Parsamian

in conversation with Bo Reipurth

Q: *First of all, congratulations with your 85th birthday! For your thesis you did photometry and polarimetry of cometary nebulae. How did you get interested in young stars, and who was your adviser?*

A: My general interest in astronomy began already in early childhood, in primary school. Later I graduated from the Physics and Mathematics Department of Yerevan State University; among the professors were Ambartsumian, Markarian, and Gurzadian (who later became adviser of my PhD thesis), and other well-known Armenian scholars. When I started to work at the Byurakan Observatory in 1954, one of its main areas of study were non-stationary phenomena in stars and galaxies, in particular, the study of T Tauri type stars and related cometary nebulae. At that time Ambartsumian (1947-1949) showed that the process of star formation takes place in the present epoch in young star clusters, which he called stellar associations. At the suggestion of Ambartsumian, I became involved in the studies of cometary nebulae.

Q: *In 1965 you published a first catalog of such cometary nebulae. One of these objects, Parsamian 21, has become famous. What is known about this star today?*

A: After the appearance of the Palomar Sky Survey, Ambartsumian set the task of finding new cometary nebulae. The catalog mentioned by you was the first result of these studies, and contained only a small portion of the objects discovered. Later, in 1979, they were included in another catalog, compiled by me and my co-worker V. Petrosyan. Among these nebulae are so many interesting objects which have been the subject of study by many astronomers. One of them is the nebulous object Parsamian 21. At a distance of 400 pc, this object (HBC 687) is perhaps best known for its prominent cometary nebula. Although no outburst has been recorded for this object, Parsamian 21 was identified as a FU Orionis source on the basis of characteristic P Cygni line profiles indicating mass loss and the double absorption lines indicating disk rotation, as identified by Staude & Neckel (1992). They also found that next to the nebula there is a Herbig-Haro object (HH 221). More recently, Tom Greene and collaborators found a great similarity between high-resolution near-infrared spectra of FU Ori and Parsamian 21.

Q: *Ambartsumian first proposed that T Tauri stars are young objects. Was he an inspiration and active influence in your work?*

A: Ambartsumian's work and ideas inspired many generations of scientists all over the world in different fields of science. Naturally, I was no exception. My direct scientific cooperation with Ambartsumian was in the field of flare stars. It was reflected in a series of four papers "Flare stars in the Pleiades" (Ambartsumian, Mirzoyan, Parsamian et al.), performed in the late 70s of the last century. He was never my direct supervisor, but his ideas, his great scientific authority in the world, his approach to science had a tremendous influence on the formation of my scientific views and interests. Therefore, I consider myself his disciple.

Q: *You spent a number of years working in Mexico. How did that come about?*

A: In the field of flare stars, Byurakan Observatory collaborated with Tonantzintla Observatory (now INAOE), directed by Guillermo Haro, whose views largely coincided with the views of Ambartsumian on the problem of flare stars. It was at the invitation of Haro, in the framework of cooperation between the two observatories, that I went to Mexico, which I repeatedly visited since 1968.

Q: *Guillermo Haro performed the first surveys for Hα emission stars in the Orion Nebula Cluster, and later you collected and augmented all these stars into the well known Parsamian-Chavira catalog. How did that project get initiated?*

A: A large number of Hα emission stars (255), in the region of the Orion Nebula were known as a result of Haro's work in the early 1950's. Subsequent to Haro's original survey, a large number of observations of the Orion Nebula region were carried out by Enrique Chavira with the Tonantzintla Schmidt Telescope (during 27 years), and using photographic plates. My search for Hα objects on those plates led to me finding an additional 240 new emission stars. In 1982 together with Chavira I published a catalog of Hα stars, adding the newly discovered stars to Haro's previous list.

Q: *You have made extensive studies of flare stars in star forming regions. How did you do those observations, and what did you learn?*

A: In the 60's and 70's of the last century, the study of flare stars was an important area in astrophysics of stars. It was pursued by scientists from many countries, but the main studies were conducted, in particular, at the Byurakan, Tonantzintla, and Asiago Observatories. I was directly involved in the investigations of flare stars, carried out at these observatories. For my part, I have discovered dozens of flare stars and hundreds of flares, and have also carried out various kinds of statistical analyses. I think that the most important of them is the discovery and study of the relationship (in the form of equations) between the maximum amplitude (energy) of flares and the ages of the stars. This relationship was the basis of the method of determining the age of flare stars and clusters. This method was highly appreciated by Ambartsumian, as an alternative method of determining the age of the clusters. Among other works I can mention the determination of the frequency distribution function of flare stars in the Orion association following the method proposed by Ambartsumian, as well as the work in which a relationship was established between the depth of a flare in the photosphere and the duration of the flare. It was shown that strong flares more frequently take place in the deep layers of the photosphere. All of these results, along with others not mentioned here, came into my second thesis (Doctor of Physics and Mathematical Sciences, 1983).

Q: *You have written a number of papers on what was called subfuors, now more commonly known as EXors, especially on V1118 Ori and V1143 Ori. Why are these two stars particularly interesting?*

A: In 1982-83, V1143 Ori and V1118 Ori in the Orion association were discovered to have major brightness variations. Previously, such large variability had been studied by Herbig in VY Tau, EX Lup, and some other stars. A characteristic feature of all these objects is a slow increase in brightness sometimes over 100 days or more, a longer period at maximum brightness with small fluctuations, and then a subsequent slow decay. The whole process takes place on a timescale of up to 1.5 years. Ambartsumian coined the term subfuors for these stars, and Herbig called them EXors. My colleague from Spain, Jose Garcia, systematically monitored V1118 Ori for more than two decades, so we have a complete picture of the activity of the star for a long time. The reason that I became interested in these stars was certain similarities of their outbursts with slow flares of flare stars and the outbursts of FUors (albeit on different scales). Our studies have also pointed to an evolutionary relationship between these objects and stars such as T Tauri. When interpreting this phenomenon I assume the hypothesis that Ambartsumian had for the FUors, which in my opinion is undeservedly forgotten. According to Ambartsumian "...An explanation is offered for this phenomenon, based on the assumption of the presence, prior to the rise in the light curve in the region adjacent to the star, of sources of corpuscular radiation. As indicated by observations, at the time of the rise in brightness, an envelope encompassing those external sources is developed. For that reason, following the rise in brightness, almost all energy from those sources is emitted in the form of thermal radiation flux."

Q: *Alongside your astronomical research, you have devoted much effort to archaeoastronomy in Armenia. Which are the main results?*

A: The Armenian highland is one of the ancient cradles of civilization. Many early investigators of the history of astronomy concluded that the ancient inhabitants of Armenia not only knew, but also took part in the formation of ancient astronomy (Maunder 1906, Olcott, 1914), but they had very little factual information to build on. The discoveries made during the last decades in Armenia have documented this and enriched our knowledge of the ancient civilization and astronomy in this region. Two regions stand out.

(i) Mezamor

On the bank of the river Mezamor, some 30 km west of Yerevan, a metal-producing centre was found, dating back to the third-fourth millennium BC. One of the most important discoveries was the complex of platforms for astronomical observations on the Small Hill of Mezamor (Parsamian, Mkrtchian 1967-69). It was shown that in the years between 2800-2600 BC, Sirius could have been observed at Solstice in the morning, in the rays of the rising Sun, in the so-called heliacal rising of Sirius. It is possible that, like the ancient Egyptians, the inhabitants of Mezamor related the first appearance of Sirius with the opening of the year.

(ii) Megalithic monument Zoraz Kar (Karahunge)

Among the ancient monuments in Armenia there is a megalithic monument, probably connected with astronomy. 250 km south-east of Yerevan there is a structure, Zoraz Kar (Karahundj), dating back to the II millennium BC. There are vertical megaliths, many of which are more than two meters in height, which form stone rings resembling the ancient stone monuments, called henges, in Great Britain and Britanny (Parsamian 1984-99; Khunkikian 1984; Parsamian, Barsegian 1987; Heruni 1999). In closing, I want to cite Prof. G.S. Hawkins, well-known from his works on Stonehenge. In his letter to Ambartsumian in 1967 he wrote: " I spoke with Elma Parsamian at the I.A.U. Conference in Prague. I think that her work at Metsamor (Mezamor) is very good and she should be encouraged to continue. I am sure that the astronomical alignments at Stonehenge are not unique and would expect to find such astronomical culture in Armenia".

Abstracts of recently accepted papers

Mopra CO Observations of the Bubble HII Region RCW120

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We use the Mopra radio telescope to test for expansion of the molecular gas associated with the bubble HII region RCW120. A ring, or bubble, morphology is common for Galactic HII regions, but the three-dimensional geometry of such objects is still unclear. Detected near- and far-side expansion of the associated molecular material would be consistent with a three-dimensional spherical object. We map the $J = 1$–0 transitions of ^{12}CO, ^{13}CO, C^{18}O, and C^{17}O, and detect emission from all isotopologues. We do not detect the 0_0–$1_{-1}E$ masing lines of CH_3OH at 108.8939 GHz. The strongest CO emission is from the photodissociation region (PDR), and there is a deficit of emission toward the bubble interior. We find no evidence for expansion of the molecular material associated with RCW120 and therefore can make no claims about its geometry. The lack of detected expansion is roughly in agreement with models for the time-evolution of an HII region like RCW120, and is consistent with an expansion speed of <1.5 km s^{-1}. Single-position CO spectra show signatures of expansion, which underscores the importance of mapped spectra for such work. Dust temperature enhancements outside the PDR of RCW120 coincide with a deficit of emission in CO, confirming that these temperature enhancements are due to holes in the RCW120 PDR. Hα emission shows that RCW120 is leaking $\sim$5% of the ionizing photons into the interstellar medium (ISM) through PDR holes at the locations of the temperature enhancements. Hα emission also shows a diffuse "halo" from leaked photons not associated with discrete holes in the PDR. Overall 25$\pm$10% of all ionizing photons are leaking into the nearby ISM.

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http://arxiv.org/pdf/1412.6470

The VLTI / PIONIER near-infrared interferometric survey of southern T Tauri stars. I. First results

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Context. The properties of the inner disks of bright Herbig AeBe stars have been studied with near infrared (NIR) interferometry and high resolution spectroscopy. The continuum and a few molecular gas species have been studied close to the central star; however, sensitivity problems limit direct information about the inner disks of the fainter T Tauri stars.
Aims. Our aim is to measure some of the properties of the inner regions of disks surrounding southern T Tauri stars.
Methods. We performed a survey with the PIONIER recombiner instrument at H-band of 21 T Tauri stars. The baselines used ranged from 11 m to 129 m, corresponding to a maximum resolution of 3 mas (0.45 AU at 150 pc).
Results. Thirteen disks are resolved well and the visibility curves are fully sampled as a function of baseline in the range 45–130 m for these 13 objects. A simple qualitative examination of visibility profiles allows us to identify a rapid drop-off in the visibilities at short baselines in 8 resolved disks. This is indicative of a significant contribution from an extended contribution of light from the disk. We demonstrate that this component is compatible with scattered light, providing strong support to a prediction made by Pinte et al. (2008). The amplitude of the drop-off and the amount of dust thermal emission changes from source to source suggesting that each disk is different. A by-product of the survey is the identification of a new milli-arcsec separation binary: WW Cha. Spectroscopic and interferometric data of AK Sco have also been fitted with a binary and disk model.
Conclusions. Visibility data are reproduced well when thermal emission and scattering form dust are fully considered. The inner radii measured are consistent with the expected dust sublimation radii. Modelling of AK Sco suggests a likely coplanarity between the disk and the binary's orbital plane.

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The formation of NGC 3603 young starburst cluster: "prompt" hierarchical assembly or monolithic starburst?

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The formation of very young massive clusters or 'starburst' clusters is currently one of the most widely debated topic in astronomy. The classical notion dictates that a star cluster is formed in situ in a dense molecular gas clump. The stellar radiative and mechanical feedback to the residual gas energizes the latter until it escapes the system. The newly born gas-free young cluster eventually readjusts with the corresponding mass-loss. Based on the observed substructured morphologies of many young stellar associations, it is alternatively suggested that even the smooth-profiled massive clusters are also assembled from migrating less massive subclusters. A very young (age ≈ 1 Myr), massive ($> 10^4 M_\odot$) star cluster like the Galactic NGC 3603 young cluster (HD 97950) is an appropriate testbed for distinguishing between the above 'monolithic' and 'hierarchical' formation scenarios. A recent study by Banerjee & Kroupa demonstrates that the monolithic scenario remarkably reproduces the HD 97950 cluster. In particular, its shape, internal motion and the mass distribution of stars are found to follow naturally and consistently from a single model calculation undergoing ≈ 70 per cent by mass gas dispersal. In this work, we explore the possibility of the formation of the above cluster via hierarchical assembly of subclusters. These subclusters are initially distributed over a wide range of spatial volumes and have various modes of subclustering in both absence and presence of a background gas potential. Unlike the above monolithic initial system that reproduces HD 97950 very well, the same is found to be prohibitive with hierarchical assembly alone (with/without a gas potential). Only those systems which assemble promptly into a single cluster (in approx. 1 Myr) from a close separation (all within approx. 2 pc) could match the observed density profile of HD 97950

after a similar gas removal. These results therefore suggest that the NGC 3603 young cluster has formed essentially monolithically, i.e., either in situ or via a prompt assembly, followed by a substantial residual gas expulsion. Both scenarios are consistent with the inferred young age and the small age spread of this cluster. Future observations of molecular cloud filaments with ALMA and proper motion measurements of young clusters with Gaia will provide more direct tests of such birth environments.

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Ro-vibrational excitation of an organic molecule (HCN) in protoplanetary disks

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Context. Organic molecules are important constituents of protoplanetary disks. Their ro-vibrational lines observed in the near- and mid-infrared are commonly detected toward T Tauri disks. These lines are the only way to probe the chemistry in the inner few au where terrestrial planets form. To understand this chemistry, accurate molecular abundances have to be determined. This is complicated by excitation effects that include radiative pumping. Most analyses so far have made the assumption of local thermal equilibrium (LTE), which may not be fulfilled because of the high gas densities required to collisionally thermalize the vibrational levels of the molecules.
Aims. The non-LTE excitation effects of hydrogen cyanide (HCN) are studied to evaluate *(i)* how the abundance determination is affected by the LTE assumption, *(ii)* whether the ro-vibrational excitation is dominated by collisions or radiative pumping, and *(iii)* which regions of protoplanetary disks are traced by certain vibrational bands.
Method. Starting from estimates for the collisional rate coefficients of HCN, non-LTE slab models of the HCN emission were calculated to study the importance of different excitation mechanisms. Using a new radiative transfer model, the HCN emission from a full two-dimensional disk was then modeled to study the effect of the non-LTE excitation, together with the line formation. We ran models tailored to the T Tauri disk AS 205 (N) where HCN lines in both the 3 μm and 14 μm bands have been observed by VLT-CRIRES and the *Spitzer Space Telescope*.
Results. Reproducing the observed 3 μm / 14 μm flux ratios requires very high densities and kinetic temperatures ($n > 10^{14}$ cm^{-3} and $T > 750$ K), if only collisional excitation is accounted for. Radiative pumping can, however, excite the lines easily out to considerable radii $\sim$ 10 au. Consequently, abundances derived from LTE and non-LTE models do not differ by more than a factor of about 3. Models with both a strongly enhanced abundance within $\sim$ 1 au (jump abundance) and constant abundance can reproduce the current observations, but future observations with the MIRI instrument on JWST and METIS on the E-ELT can easily distinguish between the scenarios and test chemical models. Depending on the scenario, ALMA can detect rotational lines within vibrationally excited levels.
Conclusions. Pumping by the continuum radiation field can bring HCN close enough to the LTE so that no big deviations in derived abundances are introduced with the LTE assumption, but the line profiles are substantially altered. In non-LTE models, accounting for collisional and radiative excitation, the emitting region can be much larger than in LTE models. Because HCN can be radiatively pumped to considerable radii, deriving a small emitting region from observations can thus point to the chemical abundance structure (e.g., jump abundance). Owing to their level structure, CO_2 and C_2H_2 are expected to act in a similar way, facilitating studies of the warm inner disk chemistry.

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Vulcan Planets: Inside-Out Formation of the Innermost Super-Earths

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The compact multi-transiting systems discovered by *Kepler* challenge traditional planet formation theories. These fall into two broad classes: (1) formation further out followed by migration; (2) formation *in situ* from a disk of gas and planetesimals. In the former, an abundance of resonant chains is expected, which the *Kepler* data do not support. In the latter, required disk mass surface densities may be too high. A recently proposed mechanism hypothesizes that planets form *in situ* at the pressure trap associated with the dead-zone inner boundary (DZIB) where radially drifting "pebbles" accumulate. This scenario predicts planet masses (M_p) are set by the gap-opening process that then leads to DZIB retreat, followed by sequential, inside-out planet formation (IOPF). For typical disk accretion rates, IOPF predictions for M_p, M_p versus orbital radius r, and planet-planet separations are consistent with observed systems. Here we investigate the IOPF prediction for how the masses, $M_{p,1}$, of the innermost ("Vulcan") planets vary with r. We show that for fiducial parameters, $M_{p,1} \simeq 5.0(r/0.1\,\mathrm{AU})\,M_{earth}$, independent of the disk's accretion rate at time of planet formation. Then, using Monte Carlo sampling of a population of these innermost planets, we test this predicted scaling against observed planet properties, allowing for intrinsic dispersions in planetary densities and *Kepler's* observational biases. These effects lead to a slightly shallower relation $M_{p,1} \propto r^{0.9\pm0.2}$, which is consistent with $M_{p,1} \propto r^{0.7\pm0.2}$ of the observed Vulcans. The normalization of the relation constrains the gap-opening process, favoring relatively low viscosities in the inner dead zone.

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Observations of water with *Herschel*/HIFI toward the high-mass protostar AFGL 2591

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Water is a key chemical species in the process of star formation, and a sensitive tracer of physical conditions in star-forming regions because of its rich line spectrum and large abundance variations between hot and cold regions. We use spectrally resolved observations of rotational lines of H_2O and its isotopologs to constrain the physical conditions of the water emitting region toward the high-mass protostar AFGL 2591. *Herschel*-HIFI spectra from 552 up to 1669 GHz show emission and absorption in 14 lines of H_2O, $H_2{}^{18}O$, and $H_2{}^{17}O$. We decompose the line profiles into contributions from the protostellar envelope, the bipolar outflow, and a foreground cloud. We use analytical estimates and rotation diagrams to estimate excitation temperatures and column densities of H_2O in these components. Furthermore, we use the non-LTE radiative transfer code RADEX to estimate the temperature and volume density of the H_2O emitting gas. Assuming LTE, we estimate an excitation temperature of ∼42 K and a column density of $\sim2\times10^{14}$ cm^{-2} for the envelope and ∼45 K and $\sim4\times10^{13}$ cm^{-2} for the outflow, in beams of 4" and 3", respectively. Non-LTE models indicate a kinetic temperature of ∼60–230 K and a volume density of $\sim7\times10^{6}$–10^{8} cm^{-3} for the envelope, and a kinetic temperature of ∼70–90 K and a gas density of $\sim10^{7}$–10^{8} cm^{-3} for the outflow. The o/p ratio of the narrow cold foreground absorption is lower than three (∼1.9±0.4), suggesting a low temperature. In contrast, the o/p ratio seen in absorption by the outflow is about 3.5±1.0, as expected for warm gas. The water abundance in the outer envelope of AFGL 2591 is $\sim10^{-9}$ for a source size of 4", similar to the low values found for other high-mass and low-mass protostars, suggesting that this abundance is rather constant during the embedded phase of high-mass star formation. The water abundance in the outflow is $\sim10^{-10}$ for a source size of 30", which is ∼10× lower than in the envelope and in the outflows of high-mass and low-mass protostars. Since beam size effects can only increase this estimate by a factor of 2, we suggest that the water in the AFGL 2591 outflow is affected by dissociating UV radiation

due to the low extinction in the outflow lobe.

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Astrochemistry at work in the L1157–B1 shock: acetaldehyde formation

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The formation of complex organic molecules (COMs) in protostellar environments is a hotly debated topic. In particular, the relative importance of the gas phase processes as compared to a direct formation of COMs on the dust grain surfaces is so far unknown. We report here the first high-resolution images of acetaldehyde (CH_3CHO) emission towards the chemically rich protostellar shock L1157-B1, obtained at 2 mm with the IRAM Plateau de Bure interferometer. Six blueshifted CH_3CHO lines with E_u = 26-35 K have been detected. The acetaldehyde spatial distribution follows the young ($\sim$ 2000 yr) outflow cavity produced by the impact of the jet with the ambient medium, indicating that this COM is closely associated with the region enriched by iced species evaporated from dust mantles and released into the gas phase. A high CH_3CHO relative abundance, 2–3 $\times$ 10^{-8}, is inferred, similarly to what found in hot-corinos. Astrochemical modelling indicates that gas phase reactions can produce the observed quantity of acetaldehyde only if a large fraction of carbon, of the order of 0.1%, is locked into iced hydrocarbons.

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The Interstellar Medium and star formation on kpc size scales

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By resimulating a region of a global disc simulation at higher resolution, we resolve and study the properties of molecular clouds with a range of masses from a few 100's $M_\odot$ to 10^6 $M_\odot$. The purpose of our paper is twofold, i) to compare the ISM and GMCs at much higher resolution compared to previous global simulations, and ii) to investigate smaller clouds and characteristics such as the internal properties of GMCs which cannot be resolved in galactic simulations. We confirm the robustness of cloud properties seen in previous galactic simulations, and that these properties extend to lower mass clouds, though we caution that velocity dispersions may not be measured correctly in poorly resolved clouds. We find that the properties of the clouds and ISM are only weakly dependent on the details of local stellar feedback, although stellar feedback is important to produce realistic star formation rates and agreement with the Schmidt-Kennicutt relation. We study internal properties of GMCs resolved by $10^4 - 10^5$ particles. The clouds are highly structured, but we find clouds have a velocity dispersion radius relationship which overall agrees with the Larson relation. The GMCs show evidence of multiple episodes of star formation, with holes corresponding to previous feedback events and dense regions likely to imminently form stars. Our simulations show clearly long filaments, which are seen predominantly in the inter-arm regions, and shells.

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Synthetic CO, H_2 and HI surveys of the Galactic 2nd Quadrant, and the properties of molecular gas

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We present CO, H_2, HI and HISA distributions from a set of simulations of grand design spirals including stellar feedback, self-gravity, heating and cooling. We replicate the emission of the 2nd Galactic Quadrant by placing the observer inside the modelled galaxies and post process the simulations using a radiative transfer code, so as to create synthetic observations. We compare the synthetic datacubes to observations of the 2nd Quadrant of the Milky Way to test the ability of the current models to reproduce the basic chemistry of the Galactic ISM, as well as to test how sensitive such galaxy models are to different recipes of chemistry and/or feedback.

We find that models which include feedback and self-gravity can reproduce the production of CO with respect to H_2 as observed in our Galaxy, as well as the distribution of the material perpendicular to the Galactic plane. While changes in the chemistry/feedback recipes do not have a huge impact on the statistical properties of the chemistry in the simulated galaxies, we find that the inclusion of both feedback and self-gravity are crucial ingredients, as our test without feedback failed to reproduce all of the observables. Finally, even though the transition from H_2 to CO seems to be robust, we find that all models seem to underproduce molecular gas, and have a lower molecular to atomic gas fraction than is observed. Nevertheless, our fiducial model with feedback and self-gravity has shown to be robust in reproducing the statistical properties of the basic molecular gas components of the ISM in our Galaxy.

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The Gould's Belt Very Large Array Survey IV: The Taurus-Auriga complex

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We present a multi-epoch radio study of the Taurus-Auriga star-forming complex made with the Karl G. Jansky Very Large Array at frequencies of 4.5 GHz and 7.5 GHz. We detect a total of 610 sources, 59 of which are related to young stellar objects and 18 to field stars. The properties of 56% of the young stars are compatible with non-thermal radio emission. We also show that the radio emission of more evolved young stellar objects tends to be more non-thermal in origin and, in general, that their radio properties are compatible with those found in other star forming regions. By comparing our results with previously reported X-ray observations, we notice that young stellar objects in Taurus-Auriga follow a Güdel-Benz relation with κ=0.03, as we previously suggested for other regions of star formation. In general, young stellar objects in Taurus-Auriga and in all the previous studied regions seem to follow this relation with a dispersion of $\sim$ 1 dex. Finally, we propose that most of the remaining sources are related with extragalactic objects but provide a list of 46 unidentified radio sources whose radio properties are compatible with a YSO nature.

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On the asymmetry of the OH ro-vibrational lines in HD 100546

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We present multi-epoch high-spectral resolution observations with VLT/CRIRES of the OH doublet $^2\Pi_{3/2}$ P4.5 (1+,1-) (2.934 μm) towards the protoplanetary disk around HD 100546. The OH doublet is detected at all epochs and is spectrally resolved while nearby H_2O lines remains undetected. The OH line velocity profile is different in the three datasets: in the first epoch (April 2012, PA=26°) the OH lines are symmetric and line broadening is consistent with the gas being in Keplerian rotation around the star. No OH emission is detected within a radius of 8-11 au from the star: the line emitting region is similar in size and extent to that of the CO ro-vibrational lines. In the other two epochs (March 2013 and April 2014, PA=90° and 10°, respectively) the OH lines appear asymmetric and fainter compared to April 2012. We investigate the origin of these line asymmetries which were taken by previous authors as evidence for tidal interaction between an (unseen) massive planet and the disk. We show that the observed asymmetries can be fully explained by a misalignment of the slit of order 0.04"-0.20" with respect to the stellar position. The disk is spatially resolved and the slit misalignment is likely caused by the extended dust emission which is brighter than the stellar photosphere at near-infrared wavelengths which is the wavelength used for the pointing. This can cause the photo-center of HD 100546 to be mis-aligned with the stellar position at near-infrared wavelengths.

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The Gaia-ESO Survey: Chromospheric Emission, Accretion Properties, and Rotation in γ Velorum and Chamaeleon I

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One of the scopes of the Gaia-ESO Survey (GES), which is conducted with FLAMES at the VLT, is the census and the characterization of the low-mass members of very young clusters and associations. We conduct a comparative study of the main properties of the sources belonging to γ Velorum (γ Vel) and Chamaeleon I (Cha I) young associations, focusing on their rotation, chromospheric radiative losses, and accretion. We use the fundamental parameters (effective temperature, surface gravity, lithium abundance, and radial velocity) delivered by the GES consortium in the first internal data release to select the members of γ Vel and Cha I among the UVES and GIRAFFE spectroscopic observations. A total of 140 γ Vel members and 74 Cha I members were studied. The procedure adopted by the GES to derive stellar fundamental parameters provided also measures of the projected rotational velocity ($v \sin i$). We calculated stellar luminosities through spectral energy distributions, while stellar masses were derived by comparison with evolutionary tracks. The spectral subtraction of low-activity and slowly rotating templates, which are rotationally broadened to match the $v \sin i$ of the targets, enabled us to measure the equivalent widths (EWs) and the fluxes in the Hα and Hβ lines. The Hα line was also used for identifying accreting objects, on the basis of its equivalent width and the width at the 10% of the line peak (10%W), and for evaluating the mass accretion rate ($\dot{M}_{\rm acc}$). The distribution of $v \sin i$ for the members of γ Vel displays a peak at about 10 km s^{-1} with a tail toward faster rotators. There is also some indication of a different $v \sin i$ distribution for the members of its two kinematical populations. Most of these stars have Hα fluxes corresponding to a saturated activity regime. We find a similar distribution, but with a narrower peak, for Cha I. Only a handful of stars in γ Vel display signatures of accretion, while many more accretors were detected in the younger Cha I, where the highest Hα fluxes are mostly due to accretion, rather than to chromospheric activity. Accreting and active stars occupy two different regions in a $T_{\rm eff}$–flux diagram and we propose a criterion for distinguishing them. We derive $\dot{M}_{\rm acc}$ in the ranges 10^{-11}–$10^{-9} M_\odot$ yr^{-1} and 10^{-10}–$10^{-7} M_\odot$ yr^{-1} for γ Vel and Cha I accretors, respectively. We find less scatter in the $\dot{M}_{\rm acc} - M_\star$ relation derived through the Hα EWs, when compared to the Hα 10%W diagnostics, in agreement with other authors.

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Formation of dense structures induced by filament collisions. Correlation of density, kinematics and magnetic field in the Pipe nebula.

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Context. The Pipe nebula is a molecular cloud that lacks star formation feedback and has a relatively simple morphology and velocity structure. This makes it an ideal target to test cloud evolution through collisions.
Aims. We aim at drawing a comprehensive picture of this relatively simple cloud to better understand the formation and evolution of molecular clouds on large scales.
Methods. We use archival data to compare the optical polarization properties, the visual extinction, and the ^{13}CO velocities and linewidths of the entire cloud in order to identify trends among the observables.
Results. The Pipe nebula can be roughly divided in two filaments with different orientations and gas velocity ranges: E–W at 2-4 km s^{-1} and N–S at 6–7 km s^{-1}. The two filaments overlap at the bowl, where the gas shows a velocity gradient spanning from 2 to 7 km s^{-1}. Compared to the rest of the Pipe nebula, the bowl gas appears to be denser and exhibits larger linewidths. In addition, the polarization data at the bowl shows lower angular dispersion and higher polarization degree. Cores in the bowl tend to cluster in space and tend to follow the ^{13}CO velocity gradient. In the stem, cores tend to cluster in regions with properties similar to those of the bowl.
Conclusions. The velocity pattern points to a collision between the filaments in the bowl region. The magnetic field seems to be compressed and strengthened in the shocked region. The proportional increase of density and magnetic field strength by a factor similar to the Alfvénic Mach number suggests a continuous shock at low Alfvénic Mach number under flux-freezing. Shocked regions seem to enhance the formation and clustering of dense cores.

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Astrochemical Correlations in Molecular Clouds

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We investigate the spectral correlations between different species used to observe molecular clouds. We use hydrodynamic simulations and a full chemical network to study the abundances of over 150 species in typical Milky Way molecular clouds. We perform synthetic observations in order to produce emission maps of a subset of these tracers. We study the effects of different lines of sight and spatial resolution on the emission distribution and perform a robust quantitative comparison of the species to each other. We use the Spectral Correlation Function (SCF), which quantifies the root mean squared difference between spectra separated by some length scale, to characterize the structure of the simulated cloud in position-position-velocity (PPV) space. We predict the observed SCF for a broad range of observational tracers, and thus, identify homologous species. In particular, we show that the pairs C and CO, C^+ and CN, NH_3 and H_2CS have very similar SCFs. We measure the SCF slope variation as a function of beam size for all species and demonstrate that the beam size has a distinct effect on different species emission. However, for beams of up to 10″, placing the cloud at 1 kpc, the change is not large enough to move the SCF slopes into different regions of parameter space. The results from this study provide observational guidance for choosing the best tracer to probe various cloud length scales.

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Turbulence decay and cloud core relaxation in molecular clouds

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The turbulent motion within molecular clouds is a key factor controlling star formation. Turbulence supports molecular cloud cores from evolving to gravitational collapse and hence sets a lower bound on the size of molecular cloud cores in which star formation can occur. On the other hand, without a continuous external energy source maintaining the turbulence, such as in molecular clouds, the turbulence decays with an energy dissipation time comparable to the dynamic timescale of clouds, which could change the size limits obtained from Jean's criterion by assuming constant turbulence intensities. Here we adopt scaling relations of physical variables in decaying turbulence to analyze its specific effects on the formation of stars. We find that the decay of turbulence provides an additional approach for Jeans' criterion to be achieved, after which gravitational infall governs the motion of the cloud core. This epoch of turbulence decay is defined as cloud core relaxation. The existence of cloud core relaxation provides a more complete understanding in the competition between turbulence and gravity on the dynamics of molecular cloud cores and star formation.

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Herschel Far-Infrared Spectral-mapping of Orion BN/KL Outflows: Spatial Distribution of Excited CO, H_2O, OH, O, and C^+ in Shocked Gas

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We present $\sim 2' \times 2'$ spectral-maps of Orion Becklin-Neugebauer/Kleinmann-Low (BN/KL) outflows taken with *Herschel* at $\sim 12''$ resolution. For the first time in the far-IR domain, we spatially resolve the emission associated with the bright H_2 shocked regions "Peak 1" and "Peak 2" from that of the hot core and ambient cloud. We analyze the $\sim$54-310 μm spectra taken with the PACS and SPIRE spectrometers. More than 100 lines are detected, most of them rotationally excited lines of ^{12}CO (up to J=48-47), H_2O, OH, ^{13}CO, and HCN. Peaks 1/2 are characterized by a very high $L(\mathrm{CO})/L_{FIR} \approx 5 \times 10^{-3}$ ratio and a plethora of far-IR H_2O emission lines. The high-J CO and OH lines are a factor of $\approx$2 brighter toward Peak 1 whereas several excited H_2O lines are $\lesssim$50% brighter toward Peak 2. Most of the CO column density arises from $T_\mathrm{k} \sim$200-500 K gas that we associate with low-velocity shocks that fail to sputter grain ice mantles and show a maximum gas-phase $H_2O/CO \leq 10^{-2}$ abundance ratio. In addition, the very excited CO ($J>35$) and H_2O lines reveal a hotter gas component ($T_\mathrm{k} \sim 2500$ K) from faster ($v_\mathrm{S} > 25$ km s^{-1}) shocks that are able to sputter the frozen-out H_2O and lead to high $H_2O/CO \geq 1$ abundance ratios. The H_2O and OH luminosities cannot be reproduced by shock models that assume high (undepleted) abundances of atomic oxygen in the preshock gas and/or neglect the presence of UV radiation in the postshock gas. Although massive outflows are a common feature in other massive star-forming cores, Orion BN/KL seems more peculiar because of its higher molecular luminosities and strong outflows caused by a recent explosive event.

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A GALEX based search for the sparse young stellar population in the Taurus-Aurigae star forming region

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In this article we search for candidates to T Tauri stars (TTSs) in the Taurus-Auriga complex within the all sky ultraviolet survey (AIS) carried out by the GALEX mission. The GALEX survey consists of 197 circular images of 0.6 deg radius covering roughly 20x20 square degrees in the sky that map the halo of the Taurus-Auriga molecular cloud, as well as, a fraction of the California Nebula and the Perseus complex; bright sources and the dark clouds themselves are avoided. GALEX images are obtained in the near ultraviolet (NUV) and far ultraviolet (FUV) bands where the TTSs show a prominent excess when compared with main sequence or giants stars. In this work, candidates are defined as sources that share UV properties with the known TTSs. For this purpose, the ultraviolet photometric properties of the T Tauri Stars (TTSs) in the GALEX bands have been defined from a template sample based on the low dispersion spectroscopic observations of the TTSs obtained with the International Ultraviolet Explorer. The TTSs candidates have been identified by means of a mixed ultraviolet-infrared excess set of colours; it is found that the colour-colour diagram FUV-NUV versus J-K is ideally suited for this purpose. From an initial sample of 163,313 bona-fidae NUV sources, a final list with 63 new candidates to TTSs in the region has been produced. The identification procedure has been validated by its ability to detect all known TTSs in the area surveyed: 31 TTSs. Also, it is shown that the weak-lined TTSs are located in a well defined stripe in the FUV-NUV versus J-K diagram. Moreover, we provide in this work a list of TTSs photometric standards for future GALEX-based studies of the young stellar population in star forming regions.

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A new approach to determine optically thick H_2 cooling and its effect on primordial star formation

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We present a new method for estimating the H_2 cooling rate in the optically thick regime in simulations of primordial star formation. Our new approach is based on the TreeCol algorithm, which projects matter distributions onto a spherical grid to create maps of column densities for each fluid element in the computational domain. We have improved this algorithm by using the relative gas velocities, to weight the individual matter contributions with the relative spectral line overlaps, in order to properly account for the Doppler effect. We compare our new method to the widely used Sobolev approximation, which yields an estimate for the column density based on the local velocity gradient and the thermal velocity. This approach generally underestimates the photon escape probability, because it neglects the density gradient and the actual shape of the cloud. We present a correction factor for the true line overlap in the Sobolev approximation and a new method based on local quantities, which fits the exact results reasonably well during the collapse of the cloud, with the error in the cooling rates always being less than 10%. Analytical fitting formulae fail at determining the photon escape probability after formation of the first protostar (error of 40%) because they are based on the assumption of spherical symmetry and therefore break down once a protostellar accretion disc has formed. Our method yields lower temperatures and hence promotes fragmentation for densities above $10^{10}\mathrm{cm}^{-3}$ at a distance of 200AU from the first protostar. Since the overall accretion rates are hardly affected by the cooling implementation, we expect Pop III stars to have lower masses in our simulations, compared to the results of previous simulations that used the Sobolev approximation.

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Pre-main sequence accretion in the low metallicity Galactic star-forming region Sh 2-284

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We present optical spectra of pre-main sequence (PMS) candidates around the Hα region taken with the Southern African Large Telescope, SALT, in the low metallicity (Z) Galactic region Sh 2-284, which includes the open cluster Dolidze 25 with an atypical low metallicity of $Z \sim 1/5\ Z_\odot$. It has been suggested on the basis of both theory and observations that PMS mass-accretion rates, $\dot{M}_{\rm acc}$, are a function of Z. We present the first sample of spectroscopic estimates of mass-accretion rates for PMS stars in any low-Z star-forming region. Our data-set was enlarged with literature data of Hα emission in intermediate-resolution R-band spectroscopy. Our total sample includes 24 objects spanning a mass range between 1 - 2 $M_\odot$ and with a median age of approximately 3.5 Myr. The vast majority (21 out of 24) show evidence for a circumstellar disk on the basis of 2MASS and *Spitzer* infrared photometry. We find $\dot{M}_{\rm acc}$ in the 1 - 2 $M_\odot$ interval to depend quasi-quadratically on stellar mass, with $\dot{M}_{\rm acc} \propto M_*^{2.4\,\pm\,0.35}$, and inversely with stellar age $\dot{M}_{\rm acc} \propto t_*^{-\,0.7\,\pm\,0.4}$. Furthermore, we compare our spectroscopic $\dot{M}_{\rm acc}$ measurements with solar Z Galactic PMS stars in the same mass range, but, *surprisingly find no evidence for a systematic change in* $\dot{M}_{\rm acc}$ *with* Z. We show that literature accretion-rate studies are influenced by detection limits, and we suggest that $\dot{M}_{\rm acc}$ may be controlled by factors other than Z_*, M_*, and age.

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The HIFI spectral survey of AFGL 2591 (CHESS). III. Chemical structure of the protostellar envelope

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We aim to understand the rich chemical composition of AFGL 2591, a prototypical isolated high-mass star-forming region.
Using HIFI and JCMT data, the abundances of molecular species found in the protostellar envelope of AFGL 2591 were derived with the Monte Carlo radiative transfer code RATRAN, assuming either constant values or 1D step-wise radial profiles as abundance distributions. The reconstructed 1D abundances were compared with the results of time-dependent gas-grain chemical modeling, considering ages of 10,000 to 50,000 years, cosmic-ray ionization rates of 0.5–50$\times 10^{-16}$ s^{-1}, uniformly-sized 0.1–1 μm dust grains, a dust/gas ratio of 1%, and several sets of initial molecular abundances with C/O <1 and >1.
Constant abundance models give good fits to the data for CO, CN, CS, HCO^+, H_2CO, N_2H^+, CCH, NO, OCS, OH, H_2CS, O, C, C^+, and CH. Models with an abundance jump at 100 K give good fits to the data for NH_3, SO, SO_2, H_2S, H_2O, HCl, and CH_3OH, while for HCN and HNC, the best models have an abundance jump at 230 K. The time-dependent chemical model can accurately explain abundance profiles of 15 out of these 24 species. The jump-like radial profiles for key species like HCO^+, NH_3, and H_2O are consistent with the outcome of the time-dependent chemical modeling. The best-fit model has a chemical age of 10-50 kyr, a solar C/O ratio of 0.44, and a cosmic-ray ionization rate of $\sim 5\times 10^{-17}$ s^{-1}; grain properties and external UV intensity do not affect the calculated chemical structure significantly.
We thus demonstrate that simple constant or jump-like abundance profiles agree with time-dependent chemical modeling for most key C-, O-, N-, and S-bearing molecules. The main exceptions are species with very few observed transitions (C, O, C^+, and CH), with a poorly established chemical network (HCl, H_2S) or whose chemistry is strongly affected by surface processes (CH_3OH).

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The SiO outflow from IRAS 17233-3606 at high resolution.

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Jets and outflows are key ingredients in the formation of stars across the mass spectrum. In clustered regions, understanding powering sources and outflow components poses a significant problem. To understand the dynamics in the outflow(s) from a cluster in the process of forming massive stars. We use new VLA observations of the molecular gas (SiO, CS, OCS and H_2CO) in the massive star forming region IRAS 17233-3606 which contains a number of HII regions. We compare these observations to previously published molecular data for this source in order to get a holistic view of the outflow dynamics. We find that the dynamics of the various species can be explained by a single large scale ($\sim$ 0.15 pc) outflow when compared to the sizes of the HII regions, with the different morphologies of the blue and red outflow components explained with respect to the morphology of the surrounding envelope. We further find that the direction of the velocity gradients seen in OCS and H_2CO are suggestive of a combination of rotation and outflow motions in the warm gas surrounding the HII regions near the base of the large scale outflow. Our results show that the massive protostars forming within this region appear to be contributing to a single outflow on large scales. This single large scale outflow is traced by a number of different species as the outflow interacts with its surroundings. On the small scales, there appear to be multiple mechanisms contributing to the dynamics which could be a combination of either a small scale outflow or rotation with the dynamics of the large scale outflow.

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An ALMA Disk Mass for the Candidate Protoplanetary Companion to FW Tau

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We present ALMA observations of the FW Tau system, a close binary pair of M5 stars with a wide-orbit (300 AU projected separation) substellar companion. The companion is extremely faint and red in the optical and near-infrared, but boasts a weak far-infrared excess and optical/near-infrared emission lines indicative of a primordial accretion disk of gas and dust. The component-resolved 1.3 mm continuum emission is found to be associated only with the companion, with a flux (1.78±0.03 mJy) that indicates a dust mass of 1–2 $M_{\oplus}$. While this mass reservoir is insufficient to form

a giant planet, it is more than sufficient to produce an analog of the Kepler-42 exoplanetary system or the Galilean satellites. The mass and geometry of the disk-bearing FW Tau companion remains unclear. Near-infrared spectroscopy shows deep water bands that indicate a spectral type later than M5, but substantial veiling prevents a more accurate determination of the effective temperature (and hence mass). Both a disk-bearing "planetary-mass" companion seen in direct light or a brown dwarf tertiary viewed in light scattered by an edge-on disk or envelope remain possibilities.

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Erosion and the limits to planetesimal growth

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The coagulation of microscopic dust into planetesimals is the first step towards the formation of planets. The composition, size, and shape of the growing aggregates determine the efficiency of this early growth. In particular, it has been proposed that fluffy ice aggregates can grow very efficiently in protoplanetary disks, suffering less from the bouncing and radial drift barriers. While the collision velocity between icy aggregates of similar size is thought to stay below the fragmentation threshold, they may nonetheless lose mass from collisions with much smaller projectiles. As a result, erosive collisions have the potential to terminate the growth of pre-planetesimal bodies. We investigate the effect of these erosive collisions on the ability of porous ice aggregates to cross the radial drift barrier. We develop a Monte Carlo code that calculates the evolution of the masses and porosities of growing aggregates, while resolving the entire mass distribution at all times. The aggregate's porosity is treated independently of its mass, and is determined by collisional compaction, gas compaction, and eventually self-gravity compaction. We include erosive collisions and study the effect of the erosion threshold velocity on aggregate growth. For erosion threshold velocities of $20-40$ m s^{-1}, high-velocity collisions with small projectiles prevent the largest aggregates from growing when they start to drift. In these cases, our local simulations result in a steady-state distribution, with the majority of the dust mass in particles with Stokes numbers close to unity. Only for the highest erosion threshold considered (60 m s^{-1}), do porous aggregates manage to cross the radial drift barrier in the inner 10 AU of MMSN-like disks. Erosive collisions are more effective in limiting the growth than fragmentary collisions between similar-size particles. Conceivably, erosion limits the growth before the radial drift barrier, although the robustness of this statement depends on (uncertain) material properties of icy aggregates. If erosion inhibits planetesimal formation through direct sticking, the sea of $\sim 10^9$ g, highly porous particles appears well-suited for triggering streaming instability.

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Protostellar Outflows and Radiative Feedback from Massive Stars

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We carry out radiation hydrodynamical simulations of the formation of massive stars in the super-Eddington regime including both their radiative feedback and protostellar outflows. The calculations start from a prestellar core of dusty gas and continue until the star stops growing. The accretion ends when the remnants of the core are ejected, mostly by the force of the direct stellar radiation in the polar direction and elsewhere by the reradiated thermal infrared radiation. How long the accretion persists depends on whether the protostellar outflows are present. We set the mass outflow rate to 1% of the stellar sink particle's accretion rate. The outflows open a bipolar cavity extending to the core's outer edge, through which the thermal radiation readily escapes. The radiative flux is funneled into the polar directions while the core's collapse proceeds near the equator. The outflow thus extends the "flashlight effect", or anisotropic radiation field, found in previous studies from the few hundred AU scale of the circumstellar disk up to the 0.1 parsec scale of the core. The core's flashlight effect allows core gas to accrete on the disk for longer, in the same way that the disk's flashlight effect allows disk gas to accrete on the star for longer. Thus although the protostellar outflows remove material near the core's poles, causing slower stellar growth over the first few free-fall times, they also enable accretion to go on longer in our calculations. The outflows ultimately lead to stars of somewhat higher mass.

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Near-IR Imaging Polarimetry toward a Bright-Rimmed Cloud: Magnetic Field in SFO 74

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We have made near-infrared (JHKs) imaging polarimetry of a bright-rimmed cloud (SFO 74). The polarization vector maps clearly show that the magnetic field in the layer just behind the bright rim is running along the rim, quite different from its ambient magnetic field. The direction of the magnetic field just behind the tip rim is almost perpendicular to that of the incident UV radiation, and the magnetic field configuration appears to be symmetric as a whole with respect to the cloud symmetry axis. We estimated the column and number densities in the two regions (just inside and far inside the tip rim) and then derived the magnetic field strength, applying the Chandrasekhar-Fermi method. The estimated magnetic field strength just inside the tip rim, 90 G, is stronger than that far inside, 30 G. This suggests that the magnetic field strength just inside the tip rim is enhanced by the UV-radiation-induced shock. The shock increases the density within the top layer around the tip and thus increases the strength of the magnetic field. The magnetic pressure seems to be comparable to the turbulent one just inside the tip rim, implying a significant contribution of the magnetic field to the total internal pressure. The mass-to-flux ratio was estimated to be close to the critical value just inside the tip rim. We speculate that the flat-topped bright rim of SFO 74 could be formed by the magnetic field effect.

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The dynamical evolution of molecular clouds near the Galactic Centre - I. Orbital structure and evolutionary timeline

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We recently proposed that the star-forming potential of dense molecular clouds in the Central Molecular Zone (CMZ, i.e. the central few 100 pc) of the Milky Way is linked to their orbital dynamics, potentially giving rise to an absolute-time sequence of star-forming clouds. In this paper, we present an orbital model for the gas stream(s) observed in the CMZ. The model is obtained by integrating orbits in the observed gravitational potential and represents a good fit to the distribution of dense gas, reproducing all of its key properties. The orbit is also consistent with observational constraints not included in the fitting process, such as the velocities of Sgr B2 and the Arches and Quintuplet clusters. It differs from previous models: (1) the orbit is open rather than closed due to the extended mass distribution in the CMZ, (2) its orbital velocity is twice as high as in previous models, and (3) Sgr A coincides with the focus of the (eccentric) orbit rather than being offset. Our orbital solution supports the scenario in which the dust ridge between G0.253+0.016 ('the Brick') and Sgr B2 represents an absolute-time sequence of star-forming clouds, triggered by the tidal compression during their recent pericentre passage. We position the clouds on a common timeline and find that their pericentre passages occurred 0.30–0.74 Myr ago. Given their short free-fall times (0.3–0.4 Myr), the quiescent cloud G0.253+0.016 and the vigorously star-forming complex Sgr B2 are separated by a single free-fall time of evolution, implying that star formation proceeds rapidly once collapse has been initiated. We provide several quantitative predictions of our model and conclude with a discussion of the model in the Galactic context, highlighting its relation to large-scale gas accretion, the dynamics of the bar, the x2 orbital family, and the origin of the Arches and Quintuplet clusters.

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Cross Sections for Planetary Systems Interacting with Passing Stars and Binaries

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Most planetary systems are formed within stellar clusters, and these environments can shape their properties. This paper considers scattering encounters between solar systems and passing cluster members, and calculates the corresponding interaction cross sections. The target solar systems are generally assumed to have four giant planets, with a variety of starting states, including circular orbits with the semimajor axes of our planets, a more compact configuration, an ultra-compact state with multiple mean motion resonances, and systems with massive planets. We then consider the effects of varying the cluster velocity dispersion, the relative importance of binaries versus single stars, different stellar host masses, and finite starting eccentricities of the planetary orbits. For each state of the initial system, we perform an ensemble of numerical scattering experiments and determine the cross sections for eccentricity increase, inclination angle increase, planet ejection, and capture. This paper reports results from over 2 million individual scattering simulations. Using supporting analytic considerations, and fitting functions to the numerical results, we find a universal formula that gives the cross sections as a function of stellar host mass, cluster velocity dispersion, starting planetary orbital radius, and final eccentricity. The resulting cross sections can be used in a wide variety of applications. As one example, we revisit constraints on the birth aggregate of our Solar System due to dynamical scattering and find $N < 10^4$ (consistent with previous estimates).

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3-D Kinematics of the near-IR HH 223 outflow in L723

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In this work we derive the full 3-D kinematics of the near-infrared outflow HH 223, located in the dark cloud Lynds 723 (L723), where a well-defined quadrupolar CO outflow is found. HH 223 appears projected onto the two lobes of the east-west CO outflow. The radio continuum source VLA 2, towards the centre of the CO outflow, harbours a multiple system of low-mass young stellar objects. One of the components has been proposed to be the exciting source of the east-west CO outflow.
From the analysis of the kinematics, we get further evidence on the relationship between the near-infrared and CO outflows and on the location of their exciting source. The proper motions were derived using multi-epoch, narrow-band H_2 (2.122 μm line) images. Radial velocities were derived from the 2.122 μm line of the spectra. Because of the extended ($\sim 5'$), S-shaped morphology of the target, the spectra were obtained with the Multi-Object-Spectroscopy (MOS) observing mode using the instrument LIRIS at the 4.2m William Herschel Telescope. To our knowledge, this work is the first time that MOS observing mode has been successfully used in the near infrared range for an extended target.

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Study of morphology and stellar content of the Galactic HII region IRAS 16148-5011

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An investigation of the IRAS 16148-5011 region - a cluster at a distance of 3.6 kpc - is presented here, carried out using multiwavelength data in near-infrared (NIR) from the 1.4m Infrared Survey Facility telescope, mid-infrared (MIR) from the archival Spitzer GLIMPSE survey, far-infrared (FIR) from the Herschel archive, and low-frequency radio continuum observations at 1280 and 843 MHz from the Giant Metrewave Radio Telescope (GMRT) and Molonglo Survey archive, respectively. A combination of NIR and MIR data is used to identify 7 Class I and 133 Class II sources in the region. Spectral Energy Distribution (SED) analysis of selected sources reveals a 9.6 Msolar, high-mass source embedded in nebulosity. However, Lyman continuum luminosity calculation using radio emission - which shows a compact HII, region - indicates the spectral type of the ionizing source to be earlier than B0-O9.5. Free-free emission SED modelling yields the electron density as 138 cm-3, and thus the mass of the ionized hydrogen as 16.4 Msolar. Thermal dust emission modelling, using the FIR data from Herschel and performing modified blackbody fits, helped us construct the temperature and column density maps of the region, which show peak values of 30 K and $3.3\text{x}10^{22}$ cm-2, respectively. The column density maps reveal an AV> 20 mag extinction associated with the nebular emission, and weak filamentary structures connecting dense clumps. The clump associated with this IRAS object is found to have dimensions of 1.1 pc x 0.8 pc, and a mass of 1023 Msolar.

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Shadows cast by a warp in the HD 142527 protoplanetary disk

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Detailed observations of gaps in protoplanetary disks have revealed structures that drive current research on circumstellar disks. One such feature is the two intensity nulls seen along the outer disk of the HD 142527 system, which are particularly well traced in polarized differential imaging. Here we propose that these are shadows cast by the inner disk. The inner and outer disk are thick, in terms of the unit-opacity surface in H-band, so that the shape and orientation of the shadows inform on the three-dimmensional structure of the system. Radiative transfer predictions on a parametric disk model allow us to conclude that the relative inclination between the inner and outer disks is $70^\circ \pm 5^\circ$. This finding taps the potential of high-contrast imaging of circumstellar disks, and bears consequences on the gas dynamics of gapped disks, as well as on the physical conditions in the shadowed regions.

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CO mass upper limits in the Fomalhaut ring - the importance of NLTE excitation in debris discs and future prospects with ALMA

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In recent years, gas has been observed in an increasing number of debris discs, though its nature remains to be determined. Here, we analyse CO molecular excitation in optically thin debris discs, and search ALMA Cycle-0 data for CO J=3-2 emission in the Fomalhaut ring. No significant line emission is observed; we set a 3-σ upper limit on the integrated line flux of 0.16 Jy km s^{-1}. We show a significant dependency of the CO excitation on the density of collisional partners n, on the gas kinetic temperature T_k and on the ambient radiation field J, suggesting that assumptions widely used for protoplanetary discs (e.g. LTE) do not necessarily apply to their low density debris counterparts. When applied to the Fomalhaut ring, we consider a primordial origin scenario where H_2 dominates collisional excitation of CO, and a secondary origin scenario dominated by e^- and H_2O. In either scenario, we obtain a strict upper limit on the CO mass of 4.9×10^{-4} $M_\oplus$. This arises in the non-LTE regime, where the excitation of the molecule is determined solely by the well-known radiation field. In the secondary scenario, assuming any CO present to be in steady state allows us to set an upper limit of ∼55% on the CO/H_2O ice ratio in the parent planetesimals. This could drop to ∼3% if LTE applies, covering the range observed in Solar System comets (0.4-30%). Finally, in light of our analysis, we present prospects for CO detection and characterisation in debris discs with ALMA.

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Star formation in turbulent molecular clouds with colliding flow

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Using self-gravitational hydrodynamical numerical simulations, we investigated the evolution of high-density turbulent molecular clouds swept by a colliding flow. The interaction of shock waves due to turbulence produces networks of thin filamentary clouds with a sub-parsec width. The colliding flow accumulates the filamentary clouds into a sheet cloud and promotes active star formation for initially high-density clouds. Clouds with a colliding flow exhibit a finer filamentary network than clouds without a colliding flow. The probability distribution functions (PDFs) for the density and column density can be fitted by lognormal functions for clouds without colliding flow. When the initial turbulence is weak, the column density PDF has a power-law wing at high column densities. The colliding flow considerably deforms the PDF, such that the PDF exhibits a double peak. The stellar mass distributions reproduced here are consistent with the classical initial mass function with a power-law index of −1.35 when the initial clouds have a high density. The distribution of stellar velocities agrees with the gas velocity distribution, which can be fitted by Gaussian functions for clouds without colliding flow. For clouds with colliding flow, the velocity dispersion of gas tends to be larger than the stellar velocity dispersion. The signatures of colliding flows and turbulence appear in channel maps reconstructed from the simulation data. Clouds without colliding flow exhibit a cloud-scale velocity shear due to the turbulence. In contrast, clouds with colliding flow show a prominent anti-correlated distribution of thin filaments between the different velocity channels, suggesting collisions between the filamentary clouds.

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Fast Modes and Dusty Horseshoes in Transitional Disks

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The brightest transitional protoplanetary disks are often azimuthally asymmetric: their mm-wave thermal emission peaks strongly on one side. Dust overdensities can exceed ∼100:1, while gas densities vary by factors less than a few. We propose that these remarkable ALMA observations—which may bear on how planetesimals form—reflect a gravitational global mode in the gas disk. The mode is (1) fast—its pattern speed equals the disk's mean Keplerian frequency; (2) of azimuthal wavenumber $m = 1$, displacing the host star from the barycenter; and (3) Toomre-stable. We solve for gas streamlines including the indirect stellar potential in the frame rotating with the pattern speed, under the drastic simplification that gas does not feel its own gravity. Near co-rotation, the gas disk takes the form of a horseshoe-shaped annulus. Dust particles with aerodynamic stopping times much shorter or much longer than the orbital period are dragged by gas toward the horseshoe center. For intermediate stopping times, dust converges toward a ∼45°-wide arc on the co-rotation circle. Particles that do not reach their final accumulation points within disk lifetimes, either because of gas turbulence or long particle drift times, conform to horseshoe-shaped gas streamlines. Our mode is not self-consistent because we neglect gas self-gravity; still, we expect that trends between accumulation location and particle size, similar to those we have found, are generically predicted by fast modes and are potentially observable. Unlike vortices, global modes are not restricted in radial width to the pressure scale height; their large radial and azimuthal extents may better match observations.

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External Photoevaporation of the Solar Nebula: Jupiter's Noble Gas Enrichments

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We present a model explaining elemental enrichments in Jupiter's atmosphere, particularly the noble gases Ar, Kr, and Xe. While He, Ne and O are depleted, seven other elements show similar enrichments (∼3 times solar, relative to H). Being volatile, Ar is difficult to fractionate from H_2. We argue that external photoevaporation by far ultraviolet (FUV) radiation from nearby massive stars removed H_2, He, and Ne from the solar nebula, but Ar and other species were retained because photoevaporation occurred at large heliocentric distances where temperatures were cold enough ($\lesssim$30 K) to trap them in amorphous water ice. As the solar nebula lost H it became relatively and uniformly enriched in other species. Our model improves on the similar model of Guillot & Hueso (2006). We recognize that cold temperatures alone do not trap volatiles; continuous water vapor production also is necessary. We demonstrate that FUV fluxes that photoevaporated the disk generated sufficient water vapor, in regions $\lesssim$30 K, to trap gas-phase species in amorphous water ice, in solar proportions. We find more efficient chemical fractionation in the outer disk: whereas the model of Guillot & Hueso (2006) predicts a factor of 3 enrichment when only $< 2\%$ of the disk mass remains, we

find the same enrichments when 30% of the disk mass remains. Finally, we predict the presence of $\sim 0.1\,M_\oplus$ of water vapor in the outer solar nebula and in protoplanetary disks in H II regions.

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Revealing the physical properties of molecular gas in Orion with a large scale survey in $J = 2$–1 lines of ^{12}CO, ^{13}CO and C^{18}O

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We present fully sampled $\sim 3'$ resolution images of the ^{12}CO ($J = 2$–1), ^{13}CO ($J = 2$–1), and C^{18}O ($J = 2$–1) emission taken with the newly developed 1.85-m mm-submm telescope toward the entire area of the Orion A and B giant molecular clouds. The data were compared with the $J = 1$–0 of the ^{12}CO, ^{13}CO, and C^{18}O data taken with the Nagoya 4-m telescope and the NANTEN telescope at the same angular resolution to derive the spatial distributions of the physical properties of the molecular gas. We explore the large velocity gradient formalism to determine the gas density and temperature by using the line combinations of ^{12}CO ($J = 2$–1), ^{13}CO ($J = 2$–1), and ^{13}CO ($J = 1$–0) assuming uniform velocity gradient and abundance ratio of CO. The derived gas density is in the range of 500 to 5000 cm^{-3}, and the derived gas temperature is mostly in the range of 20 to 50 K along the cloud ridge with a temperature gradient depending on the distance from the star forming region. We found the high-temperature region at the cloud edge facing to the HII region, indicating that the molecular gas is interacting with the stellar wind and radiation from the massive stars. In addition, we compared the derived gas properties with the Young Stellar Objects distribution obtained with the Spitzer telescope to investigate the relationship between the gas properties and the star formation activity therein. We found that the gas density and star formation efficiency are well positively correlated, indicating that stars form effectively in the dense gas region.

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Can we trace very cold dust from its emission alone ?

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Context. Dust is a good tracer of cold dark clouds but its column density is difficult to quantify.
Aims. We want to check whether the far–infrared and submillimeter high–resolution data from Herschel SPIRE and PACS cameras combined with ground–based telescope bolometers allow us to retrieve the whole dust content of cold dark clouds.
Methods. We compare far–infrared and submillimeter emission across L183 to the 8 μm absorption map from Spitzer data and fit modified blackbody functions towards three different positions.
Results. We find that none of the Herschel SPIRE channels follow the cold dust profile seen in absorption. Even the

ground-based submillimeter telescope observations, although more closely following the absorption profile, cannot help to characterize the cold dust without external information such as the dust column density itself. The difference in dust opacity can reach up to a factor of 3 in prestellar cores of high extinction.
Conclusions. In dark clouds, the amount of very cold dust cannot be measured from its emission alone. In particular, studies of dark clouds based only on Herschel data can miss a large fraction of the dust content. This has an impact on core and filament density profiles, mass and stability estimates.

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Which young clusters/associations are we missing today?

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Currently clusters/associations of stars are mainly detected as surface density enhancements relative to the background field. While clusters form, their surface density increases. It likely decreases again at the end of the star formation process when the system expands as a consequence of gas expulsion. Therefore the surface density of a single cluster can change considerably in young clusters/associations during the first 20 Myr of their development. We investigate the effect of the gas expulsion on the detectability of clusters/associations typical for the solar neighbourhood, where the star formation efficiency is <35%. The main focus will be laid on the dependence on the initial cluster mass. Nbody methods are used to determine the cluster/association dynamics after gas expulsion. We find that, even for low background densities, only clusters/associations with initial central surface densities exceeding a few 5000 $M_\odot/pc^2$ will be detected as clusters at ages $\gtrsim$ 5 Myr. Even the Orion Nebula cluster, one of the most massive nearby clusters, would only be categorized as a small co-moving group with current methods after 5 Myr of development. This means that cluster expansion leads to a selection effect - at ages of <1-2 Myr the full range of clusters/associations is observed whereas at ages > 4 Myr only the most massive clusters are identified, while systems with initially $M_c < 3\,000$ $M_\odot$ are missing. The temporal development of stellar properties is usually determined by observing clusters of different ages. The potentially strong inhomogeneity of the cluster sample makes this methods highly questionable. However, GAIA could provide the means to rectify this situation as it will be able to detect lower mass clusters.

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Minimum Core Masses for Giant Planet Formation With Realistic Equations of State and Opacities

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Giant planet formation by core accretion requires a core that is sufficiently massive to trigger runaway gas accretion in less that the typical lifetime of protoplanetary disks. We explore how the minimum required core mass, $M_{\rm crit}$, depends on a non-ideal equation of state and on opacity changes due to grain growth, across a range of stellocentric distances from 5–100 AU. This minimum $M_{\rm crit}$ applies when planetesimal accretion does not substantially heat the atmosphere. Compared to an ideal gas polytrope, the inclusion of molecular hydrogen (H_2) dissociation and variable occupation of H_2 rotational states increases $M_{\rm crit}$. Specifically, $M_{\rm crit}$ increases by a factor of $\sim$2 if the H_2 spin isomers, ortho- and parahydrogen, are in thermal equilibrium, and by a factor of $\sim$2–4 if the ortho-to-para ratio is fixed at 3:1. Lower opacities due to grain growth reduce $M_{\rm crit}$. For a standard disk model around a Solar mass star, we calculate $M_{\rm crit}$ $\sim 8\ M_\oplus$ at 5 AU, decreasing to $\sim 5\ M_\oplus$ at 100 AU, for a realistic EOS with an equilibrium ortho-to-para ratio and for grain growth to cm-sizes. If grain coagulation is taken into account, $M_{\rm crit}$ may further reduce by up to one order of magnitude. These results for the minimum critical core mass are useful for the interpretation of surveys that find

exoplanets at a range of orbital distances.

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The Habitable Zones of Pre-Main-Sequence Stars

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We calculate the pre-main-sequence HZ for stars of spectral classes F to M. The spatial distribution of liquid water and its change during the pre-main-sequence phase of protoplanetary systems is important in understanding how planets become habitable. Such worlds are interesting targets for future missions because the coolest stars could provide habitable conditions for up to 2.5 billion years post-accretion. Moreover, for a given star type, planetary systems are more easily resolved because of higher pre-main-sequence stellar luminosities, resulting in larger planet to star separation for cool stars than is the case for the traditional main-sequence (MS) habitable zone (HZ). We use 1D radiative-convective climate and stellar evolutionary models to calculate pre-main-sequence HZ distances for F1 to M8 stellar types. We also show that accreting planets that are later located in the traditional MS HZ orbiting stars cooler than a K5 (including the full range of M-stars) receive stellar fluxes that exceed the runaway greenhouse threshold, and thus may lose substantial amounts of water initially delivered to them. We predict that M-star planets need to initially accrete more water than Earth did or, alternatively, have additional water delivered later during the long pre-main-sequence phase to remain habitable. Our findings are also consistent with recent claims that Venus lost its water during accretion.

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Brown Dwarf Binaries from Disintegrating Triple Systems

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Binaries in which both components are brown dwarfs (BDs) are being discovered at an increasing rate, and their properties may hold clues to their origin. We have carried out 200,000 N-body simulations of three identical stellar embryos with masses drawn from a Chabrier IMF and embedded in a molecular core. The bodies are initially non-hierarchical and undergo chaotic motions within the cloud core, while accreting using Bondi-Hoyle accretion. The coupling of dynamics and accretion often leads to one or two dominant bodies controlling the center of the cloud core, while banishing the other(s) to the lower-density outskirts, leading to stunted growth. Eventually each system transforms either to a bound hierarchical configuration or breaks apart into separate single and binary components. The orbital motion is followed for 100 Myr. In order to illustrate 200,000 end-states of such dynamical evolution with accretion, we introduce the 'triple diagnostic diagram', which plots two dimensionless numbers against each other, representing the binary mass ratio and the mass ratio of the third body to the total system mass. Numerous freefloating BD binaries are formed in these simulations, and statistical properties are derived. The separation distribution function is in good correspondence with observations, showing a steep rise at close separations, peaking around 13 AU and declining more gently, reaching zero at separations greater than 200 AU. Unresolved BD triple systems may appear as wider BD binaries. Mass ratios are strongly peaked towards unity, as observed, but this is partially due to the initial assumptions. Eccentricities gradually increase towards higher values, due to the lack of viscous interactions in the simulations, which would both shrink the orbits and decrease their eccentricities. Most newborn triple systems are unstable and while there are 9,209 ejected BD binaries at 1 Myr, corresponding to about 4% of the 200,000 simulations, this number has grown to 15,894 at 100 Myr (∼8%). The total binary fraction among freefloating BDs is 0.43, but this

assumes that all binaries are resolved and that they are all formed from triple systems. However, the gradual breakup of higher-order multiples leads to many more singles, thus lowering the binary fraction. The main threat to newly born triple systems is internal instabilities, not external perturbations. At 1 Myr there are 1,325 BD binaries still bound to a star, corresponding to 0.66% of the simulations, but only 253 (0.13%) are stable on timescales >100 Myr. These simulations indicate that dynamical interactions in newborn triple systems of stellar embryos embedded in and accreting from a cloud core naturally form a population of freefloating BD binaries, and this mechanism may constitute a significant pathway for the formation of BD binaries.

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For a version with full resolution figures, see
http://www.ifa.hawaii.edu/publications/preprints/14preprints/Reipurth_14-248.pdf

Modeling Complex Organic Molecules in dense regions: Eley-Rideal and complex induced reaction

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Recent observations have revealed the existence of Complex Organic Molecules (COMs) in cold dense cores and prestellar cores. The presence of these molecules in such cold conditions is not well understood and remains a matter of debate since the previously proposed 'warm- up' scenario cannot explain these observations. In this article, we study the effect of Eley- Rideal and complex induced reaction mechanisms of gas-phase carbon atoms with the main ice components of dust grains on the formation of COMs in cold and dense regions. Based on recent experiments we use a low value for the chemical desorption efficiency (which was previously invoked to explain the observed COM abundances). We show that our introduced mechanisms are efficient enough to produce a large amount of complex organic molecules in the gas-phase at temperatures as low as 10K.

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The JCMT Gould Belt Survey: Evidence for radiative heating in Serpens MWC 297 and its influence on local star formation

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We present SCUBA-2 450micron and 850micron observations of the Serpens MWC 297 region, part of the JCMT Gould Belt Survey of nearby star-forming regions. Simulations suggest that radiative feedback influences the star-formation process and we investigate observational evidence for this by constructing temperature maps. Maps are derived from the ratio of SCUBA-2 fluxes and a two component model of the JCMT beam for a fixed dust opacity spectral index of beta = 1.8. Within 40 of the B1.5Ve Herbig star MWC 297, the submillimetre fluxes are contaminated by free-free emission with a spectral index of 1.03+-0.02, consistent with an ultra-compact HII region and polar winds/jets. Contamination accounts for 73+-5 per cent and 82+-4 per cent of peak flux at 450micron and 850micron respectively. The residual thermal disk of the star is almost undetectable at these wavelengths. Young Stellar Objects are confirmed where SCUBA-2 850micron clumps identified by the fellwalker algorithm coincide with Spitzer Gould Belt Survey detections. We identify 23 objects and use Tbol to classify nine YSOs with masses 0.09 to 5.1 Msun. We find two Class 0, one Class 0/I, three Class I and three Class II sources. The mean temperature is 15+-2K for the nine YSOs and 32+-4K for the 14 starless clumps. We observe a starless clump with an abnormally high mean temperature of 46+-2K and conclude that it is radiatively heated by the star MWC 297. Jeans stability provides evidence that radiative heating by the star MWC 297 may be suppressing clump collapse.

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HOPS 383: An Outbursting Class 0 Protostar in Orion

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We report the dramatic mid-infrared brightening between 2004 and 2006 of HOPS 383, a deeply embedded protostar adjacent to NGC 1977 in Orion. By 2008, the source became a factor of 35 brighter at 24 μm with a brightness increase also apparent at 4.5 μm. The outburst is also detected in the submillimeter by comparing APEX/SABOCA to SCUBA data, and a scattered-light nebula appeared in NEWFIRM K_s imaging. The post-outburst spectral energy distribution indicates a Class 0 source with a dense envelope and a luminosity between 6 and 14 $L_\odot$. Post-outburst time-series mid- and far-infrared photometry shows no long-term fading and variability at the 18% level between 2009 and 2012. HOPS 383 is the first outbursting Class 0 object discovered, pointing to the importance of episodic accretion at early stages in the star formation process. Its dramatic rise and lack of fading over a six-year period hint that it may be similar to FU Ori outbursts, although the luminosity appears to be significantly smaller than the canonical luminosities of such objects.

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Near-Infrared Image of the Debris Disk around HD 15115

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We present a Subaru/IRCS H-band image of the edge-on debris disk around the F2V star HD 15115. We detected the debris disk, which has a bow shape and an asymmetric surface brightness, at a projected separation of $1''$–$3''$ ($\sim$50–150 AU). The disk surface brightness is $\sim$0.5–1.5 mag brighter on the western side than on the eastern side. We use an inclined annulus disk model to probe the disk geometry. The model fitting suggests that the disk has an inner hole with a radius of 86 AU and an eccentricity of 0.06. The disk model also indicates that the amount of dust on the western side is 2.2 times larger than that on the eastern side. A several Jupiter-mass planet may exist at $\gtrsim$45 AU and capture grains at the Lagrangian points to open the eccentric gap. This scenario can explain both the eccentric gap and the difference in the amount of dust. In case of the stellar age of several 100 Myr, a dramatic planetesimal collision possibly causes the dust to increase in the western side. Interstellar medium interaction is also considered as a possible explanation of the asymmetric surface brightness, however, it hardly affect large grains in the vicinity of the inner hole.

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The Magnetic Field in the Class 0 Protostellar Disk of L1527

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We present subarcsecond ($\sim$0.″35) resolved observations of the 1.3 mm dust polarization from the edge-on circumstellar disk around the Class 0 protostar L1527. The inferred magnetic field is consistent with a dominantly toroidal morphology; there is no significantly detected vertical poloidal component to which observations of an edge-on disk are most sensitive. This suggests that angular momentum transport in Class 0 protostars (when large amounts of material are fed down to the disk from the envelope and accreted onto the protostar) is driven mainly by magnetorotational instability rather than magnetocentrifugal winds at 50 AU scales. In addition, with the data to date there is an early, tentative trend that $R > 30$ AU disks have so far been found in Class 0 systems with average magnetic fields on the 1000 AU scale strongly misaligned with the rotation axis. The absence of such a disk in the aligned case could be due to efficient magnetic braking that disrupts disk formation. If this is the case, this implies that candidate Class 0 disk systems could be identified by the average magnetic field direction at $\sim$1000 AU spatial scales.

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On the location of the ice line in circumbinary discs

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Position of the ice line in a circumbinary disc is determined using a simplified and illustrative model. Main sources of the heat in the energy balance of the disc, i.e. heating by the turbulence, irradiation by the components of the binary and the tidal heating are considered. Our goal is to clarify role of the tidal heating in the position of the ice line. When viscous heating and irradiation of the binary are considered, ice line lies interior to the inner radius of the disc in most of the binaries represented by our parameter survey. But tidal heating significantly extends position of the ice line to a larger radius, so that a smaller fraction of the circumbinaries' population may have ice lines interior to the inner radius of the disc.

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Orbital and physical properties of the σ Ori Aa,Ab,B triple system

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We provide a complete characterization of the astrophysical properties of the σ Ori Aa,Ab,B hierarchical triple system, and an improved set of orbital parameters for the highly eccentric σ Ori Aa,Ab spectroscopic binary.
We compiled a spectroscopic dataset comprising 90 high-resolution spectra covering a total time span of 1963 days. We applied the Lehman-Filhés method for a detailed orbital analysis of the radial velocity curves and performed a combined quantitative spectroscopic analysis of the σ Ori Aa,Ab,B system by means of the stellar atmosphere code FASTWIND. We used our own plus other available information on photometry and distance to the system for measuring the radii, luminosities, and spectroscopic masses of the three components. We also inferred evolutionary masses and stellar ages using the Bayesian code BONNSAI.
The orbital analysis of the new radial velocity curves led to a very accurate orbital solution of the σ Ori Aa,Ab pair. We provided indirect arguments indicating that σ Ori B is a fast rotating early-B dwarf. The FASTWIND+BONNSAI analysis showed that the Aa,Ab pair contains the hottest and most massive components of the triple system while σ Ori B is a bit cooler and less massive. The derived stellar ages of the inner pair are intriguingly younger than the one widely accepted for the σ Orionis cluster, at 3±1 Ma.
The outcome of this study will be of key importance for a precise determination of the distance to the σ Orionis cluster, the interpretation of the strong X-ray emission detected for σ Ori Aa,Ab,B, and the investigation of the formation and evolution of multiple massive stellar systems and substellar objects.

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The North Polar Spur and Aquila Rift

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Soft X-ray intensity at 0.89 keV along the North Polar Spur is shown to follow the extinction law due to the interstellar gas in the Aquila Rift by analyzing the ROSAT archival data, which proves that the NPS is located behind the rift. The Aquila-Serpens molecular clouds, where the X-ray optical depth exceeds unity, are shown to have a mean LSR velocity of $v = 7.33 \pm 1.94$ km s^{-1}, corresponding to a kinematic distance of $r = 0.642 \pm 0.174$ kpc. Assuming a shell structure, a lower limit of the distance to NPS is derived to be 1.01 ± 0.25 kpc, with the shell center being located farther than 1.1 kpc. Based on the distance estimation, we argue that the NPS is a galactic halo object.

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Debris Distribution in HD 95086 - A Young Analog of HR 8799

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HD 95086 is a young early-type star that hosts (1) a 5 M_J planet at the projected distance of 56 AU revealed by direct imaging, and (2) a prominent debris disk. Here we report the detection of 69 μm crystalline olivine feature from the disk using the Spitzer/MIPS-SED data covering 55–95 μm. Due to the low resolution of MIPS-SED mode, this feature is not spectrally resolved, but is consistent with the emission from crystalline forsterite contributing 5% of the total dust mass. We also present detailed analysis of the disk SED and re-analysis of resolved images obtained by Herschel. Our results suggest that the debris structure around HD 95086 consists of a warm (175 K) belt, a cold (55 K) disk, and an extended disk halo (up to 800 AU), and is very similar to that of HR 8799. We compare the properties of the three debris components, and suggest that HD 95086 is a young analog of HR 8799. We further investigate and constrain single-planet, two-planet, three-planet and four-planet architectures that can account for the observed debris structure and are compatible with dynamical stability constraints. We find that equal-mass four-planet configurations of geometrically spaced orbits, with each planet of mass 5 M_J, could maintain the gap between the warm and cold debris belts, and also be just marginally stable for timescales comparable to the age of the system.

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Chemistry in Disks. IX. Observations and modeling of HCO+ and DCO+ in DM Tau

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Aims We study the deuteration and ionization structure of the DM Tau disk via interferometric observations and modeling of the key molecular ions, HCO^+ and DCO^+.
Methods The Plateau de Bure Array is used to observe DM Tau in lines of HCO^+ (1-0), (3-2) and DCO^+ (3-2) with a $\sim$1.5" angular and $\sim 0.2\,\mathrm{km\,s^{-1}}$ spectral resolution. Using a power-law fitting approach the observed column densities profiles are derived and thus the isotopic ratio $R_D = DCO^+/HCO^+$. Chemical modeling allowed an exploration of the sensitivity of HCO^+ and DCO^+ abundances to physical parameters out with temperature. A steady state approximation was employed to observationally constrain the ionization fraction $x(e^-)$.
Results Fitting of radiative transfer models suggests that there is a chemical hole in HCO^+ and DCO^+, extending up to 50 AU from the star. More work is required to discern the cause of this. The observed column densities of HCO^+ and DCO^+ at 100 AU were $\left(9.8^{+0.3}_{-0.7}\right) \times 10^{12}$ and $(1.2 \pm 0.7) \times 10^{12}\,\mathrm{cm^{-2}}$ respectively. Where both HCO^+ and DCO^+ were present, R_D was found to increase radially from 0.1 at 50 AU to 0.2 at 450 AU. This behaviour was well reproduced by the chemical model. The X-ray luminosity of the central star, the interstellar UV and CO depletion were found to be the most important physical parameters controlling the abundances of HCO^+ and DCO^+. Differences in the vertical extent of HCO^+ and DCO^+ molecular layers resulted in different responses to changing physical parameters, manifesting as radial gradients in R_D. The ionization fraction was found to be $x(e^-) \sim 10^{-7}$ in the molecular layer, comparable to the disk averaged value. Modeling shows that while HCO^+ is the most dominant charged molecular ion in our disk model, atomic ions, such as C^+, S^+, H^+, Na^+ and Mg^+, dominate the charge in both the molecular layer and disk atmosphere.
Conclusion A high value of R_D is indicative of continued deuterium fractionation in a protoplanetary disk after pre/protostellar phases. Radial properties of R_D can be employed to discern the importance of ionization from X-rays and UV, thus necessitating the need for more, high resolution observations of DCO^+ and other deuterated species

in disks. A steady-state approach commonly adopted for constraining ionization degree in prestellar cores is not applicable for disks where accurate determination of the ionization fraction in the molecular layer requires knowledge of the atomic ions present as molecular ions are relatively sparse.

Accepted by A & A

http://arxiv.org/pdf/1501.00984

Gas composition of main volatile elements in protoplanetary discs and its implication for planet formation

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Direct observations of gaseous exoplanets reveal that their gas envelope has a higher C/O ratio than that of the host star (e.g., Wasp 12-b). This has been explained by considering that the gas phase of the disc could be inhomogeneous, exceeding the stellar C/O ratio in regions where these planets formed; but few studies have considered the drift of the gas and planet migration. We aim to derive the gas composition in planets through planet formation to evaluate if the formation of giant planets with an enriched C/O ratio is possible. The study focusses on the effects of different processes on the C/O ratio, such as the disc evolution, the drift of gas, and planet migration. We used our previous models for computing the chemical composition, together with a planet formation model, to which we added the composition and drift of the gas phase of the disc, which is composed of the main volatile species H_2O, CO, CO_2, NH_3, N_2, CH_3OH, CH_4, and H_2S, H_2 and He. The study focusses on the region where ice lines are present and influence the C/O ratio of the planets. Modelling shows that the condensation of volatile species as a function of radial distance allows for C/O enrichment in specific parts of the protoplanetary disc of up to four times the solar value. This leads to the formation of planets that can be enriched in C/O in their envelope up to three times the solar value. Planet migration, gas phase evolution and disc irradiation enables the evolution of the initial C/O ratio that decreases in the outer part of the disc and increases in the inner part of the disc. The total C/O ratio of the planets is governed by the contribution of ices accreted, suggesting that high C/O ratios measured in planetary atmospheres are indicative of a lack of exchange of material between the core of a planet and its envelope or an observational bias. It also suggests that the observed C/O ratio is not representative of the total C/O ratio of the planet.

Accepted by Astronomy and Astrophysics

http://arxiv.org/pdf/1412.5784

Five steps in the evolution from protoplanetary to debris disk

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The protoplanetary disks seen around Herbig Ae stars eventually dissipate leaving just a tenuous debris disk, comprised of planetesimals and the dust derived from them, as well as possibly gas and planets. This paper uses the properties of the youngest (10-20 Myr) A star debris disks to consider the transition from protoplanetary to debris disk. It is argued that the physical distinction between these two classes should rest on the presence of primordial gas in sufficient quantities to dominate the motion of small dust grains (rather than on the secondary nature of the dust or its level of stirring). This motivates an observational classification based on the dust emission spectrum which is empirically defined so that A star debris disks require fractional excesses < 3 at $12\,\mu$m and < 2000 at $70\,\mu$m. We also propose that a useful hypothesis to test is that the planet and planetesimal systems seen on the main sequence are already in place during the protoplanetary disk phase, but are obscured or overwhelmed by the rest of the disk. This may be only weakly true if the architecture of the planetary system continues to change until frozen at the epoch of disk dispersal, or completely false if planets and planetesimals form during the relatively short dispersal phase. Five steps

in the transition are discussed: **(i)** the well-known carving of an inner hole to form a *transition disk*; **(ii)** depletion of mm-sized dust in the outer disk, where it is noted that it is of critical importance to ascertain whether this mass ends up in larger planetesimals or is collisionally depleted; **(iii)** final clearing of inner regions, where it is noted that multiple debris-like mechanisms exist to replenish moderate levels of hot dust at later phases, and that these likely also operate in protoplanetary disks; **(iv)** disappearence of the gas, noting the recent discoveries of both primordial and secondary gas in debris disks which highlight our ignorance in this area and its impending enlightenment by ALMA; **(v)** formation of ring-like structure of planetesimals, noting that these are shaped by interactions with planets, and that the location of the planetesimals in protoplanetary disks may be unrelated to that of dust concentrations therein that are set by gas interactions.

Accepted by Astrophysics and Space Science

http://arxiv.org/pdf/1412.5598

Observations of Infalling and Rotational Motions on a 1,000-AU Scale around 17 Class 0 and 0/I Protostars: Hints of Disk Growth and Magnetic Braking?

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We perform imaging and analyses of SMA 1.3 mm continuum, $C^{18}O$ (2–1) and ^{12}CO (2–1) line data of 17 Class 0 and 0/I protostars to study their gas kinematics on a 1,000-AU scale. Continuum and $C^{18}O$ (2–1) emission are detected toward all the sample sources and show central primary components with sizes of ∼600–1,500 AU associated with protostars. The velocity gradients in $C^{18}O$ (2–1) have wide ranges of orientations from parallel to perpendicular to the outflows, with magnitudes from ∼1 to ∼530 km s^{-1} pc^{-1}. We construct a simple kinematic model to reproduce the observed velocity gradients, estimate the infalling and rotational velocities, and infer the disk radii and the protostellar masses. The inferred disk radii range from <5 AU to >500 AU with estimated protostellar masses from <0.1 $M_\odot$ to >1 $M_\odot$. Our results hint that both large and small disks are possibly present around Class 0 protostars, which could be a sign of disk growth at the Class 0 stage. In addition, the directions of the overall velocity gradients in 7 out of the 17 sources are close to perpendicular to their outflow axes ($\Delta\theta > 65^\circ$), which is a signature of significant rotational motions. From our model fitting, the specific angular momenta in these sources are estimated to be >2 × 10^{-4} km s^{-1} pc, suggesting that magnetic braking is unlikely efficient on a 1,000-AU scale in these Class 0 and 0/I sources. In a sub-sample with observed magnetic field orientations, we find no source with large specific angular momenta together with closely aligned magnetic field and outflow axes. This possibly hints that the magnetic field, if originally aligned with the rotational axis, can play a role in removing angular momentum from infalling material at the Class 0 stage. We discuss our results in comparison with theoretical models of collapsing dense cores with and without magnetic fields in the context of disk formation.

Accepted by ApJ

http://arxiv.org/pdf/1412.1916

Dust Transport in MRI Turbulent Disks: Ideal and Non-ideal MHD with Ambipolar Diffusion

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We study dust transport in turbulent protoplanetary disks using three-dimensional global unstratified magnetohydrodynamic (MHD) simulations including Lagrangian dust particles. The turbulence is driven by the magnetorotational instability (MRI) with either ideal or non-ideal MHD that includes ambipolar diffusion (AD). In ideal MHD simula-

tions, the surface density evolution (except for dust that drifts fastest), turbulent diffusion, and vertical scale height of dust can all be reproduced by simple one-dimensoinal and/or analytical models. However, in AD dominated simulations which simulate protoplanetary disks beyond 10s of AU, the vertical scale height of dust is larger than previously predicted. To understand this anomaly in more detail, we carry out both unstratified and stratified local shearing box simulations with Lagrangian particles, and find that turbulence in AD dominated disks has very different properties (e.g., temporal autocorrelation functions and power spectra) than turbulence in ideal MHD disks, which leads to quite different particle diffusion efficiency. For example, MRI turbulence with AD has a longer correlation time for the vertical velocity, which causes significant vertical particle diffusion and large dust scale height. In ideal MHD the Schmidt numbers (Sc) for radial and vertical turbulent diffusion are $Sc_r \sim 1$ and $Sc_z > 3$, but in the AD dominated regime both Sc_r and Sc_z are < 1. Particle concentration in pressure bumps induced by MRI turbulence has also been studied. Since non-ideal MHD effects dominate most regions in protoplanetary disks, our study suggests that modeling dust transport in turbulence driven by MRI with non-ideal MHD effects is important for understanding dust transport in realistic protoplanetary disks.

Accepted by ApJ

http://arxiv.org/pdf/1405.2778

Abstracts of recently accepted major reviews

Radio Jets in Young Stellar Objects with the SKA

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Jets and outflows are ubiquitous in the process of formation of stars since accretion is intimately associated with outflow. Free-free radio continuum emission in the centimeter domain is associated with these jets. The emission is weak, and sensitive telescopes are required to detect it.
One of the key problems in the study of outflows is to determine how they are accelerated and collimated. Observations in the cm range are most useful to trace the base of the ionized jets, close to the young central object and its accretion disk, where optical or near-IR images are obscured by the high extinction present. Radio recombination lines in jets (in combination with proper motions) should provide their 3D kinematics at very small scale (near their origin). SKA will be crucial to perform this kind of observations.
Thermal jets are associated with both low and high mass protostars. The ionizing mechanism of these radio jets appears to be related to shocks in the associated outflows, as suggested by the observed correlation between the centimeter luminosity and the outflow momentum rate. From this correlation and that with the bolometric luminosity of the driving star it will be possible to discriminate with SKA between unresolved HII regions and jets, and to infer physical properties of the embedded objects.
Some jets associated with young stellar objects (YSOs) show indications of non-thermal emission (negative spectral indices) in part of their lobes. Linearly polarized synchrotron emission has been found in the jet of HH 80-81, allowing us to measure the direction and intensity of the jet magnetic field, a clue ingredient in determining the collimation and ejection mechanisms. As only a fraction of the emission is polarized, very sensitive observations such as those that will be feasible with SKA are required to perform these studies.
Jets are common in many kinds of astrophysical scenarios. Characterizing radio jets in YSOs, where thermal emission allows us to determine their physical conditions in a reliable way, would be also useful in understanding acceleration and collimation mechanisms in all kinds of astrophysical jets.

Accepted as a review chapter in "Advancing Astrophysics with the Square Kilometre Array", PoS(AASKA14)121

http://arxiv.org/pdf/1412.6409

Complex organic molecules in protostellar environments in the SKA era

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Molecular complexity builds up at each step of the Sun-like star formation process, starting from simple molecules and ending up in large polyatomic species. Complex organic molecules (COMs; such as methyl formate, $HCOOCH_3$, dymethyl ether, CH_3OCH_3, formamide, NH_2CHO, or glycoaldehyde, $HCOCH_2OH$) are formed in all the components

of the star formation recipe (e.g. pre-stellar cores, hot-corinos, circumstellar disks, shocks induced by fast jets), due to ice grain mantle sublimation or sputtering as well as gas-phase reactions. Understanding in great detail the involved processes is likely the only way to predict the ultimate molecular complexity reached in the ISM, as the detection of large molecules is increasingly more difficult with the increase of the number of atoms constituting them.
Thanks to the recent spectacular progress of astronomical observations, due to the Herschel (sub-mm and IR), IRAM and SMA (mm and sub-mm), and NRAO (cm) telescopes, an enormous activity is being developed in the field of Astrochemistry, extending from astronomical observatories to chemical laboratories. We are involved in several observational projects providing unbiased spectral surveys (in the 80-300 and 500-2000 GHz ranges) with unprecedented sensitivity of templates of dense cores and protostars. Forests of COM lines have been detected. In this chapter we will focus on the chemistry of both cold prestellar cores and hot shocked regions, (i) reviewing results and open questions provided by mm–FIR observations, and (ii) showing the need of carrying on the observations of COMs at lower frequencies, where SKA will operate. We will also emphasize the importance of analysing the spectra by the light of the experimental studies performed by our team, who is investigating the chemical effects induced by ionising radiation bombarding astrophysically relevant ices.

Accepted by Proceedings of Science: Advancing Astrophysics with the Square Kilometre Array

http://arxiv.org/pdf/1412.8611

Physical Processes in the Interstellar Medium

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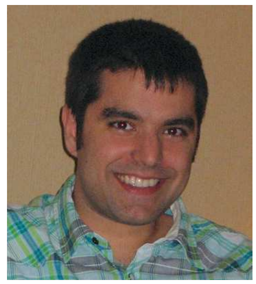
Interstellar space is filled with a dilute mixture of charged particles, atoms, molecules and dust grains, called the interstellar medium (ISM). Understanding its physical properties and dynamical behavior is of pivotal importance to many areas of astronomy and astrophysics. Galaxy formation and evolution, the formation of stars, cosmic nucleosynthesis, the origin of large complex, prebiotic molecules and the abundance, structure and growth of dust grains which constitute the fundamental building blocks of planets, all these processes are intimately coupled to the physics of the interstellar medium. However, despite its importance, its structure and evolution is still not fully understood. Observations reveal that the interstellar medium is highly turbulent, consists of different chemical phases, and is characterized by complex structure on all resolvable spatial and temporal scales. Our current numerical and theoretical models describe it as a strongly coupled system that is far from equilibrium and where the different components are intricately linked together by complex feedback loops. Describing the interstellar medium is truly a multi-scale and multi-physics problem. In these lecture notes we introduce the microphysics necessary to better understand the interstellar medium. We review the relations between large-scale and small-scale dynamics, we consider turbulence as one of the key drivers of galactic evolution, and we review the physical processes that lead to the formation of dense molecular clouds and that govern stellar birth in their interior.

Lecture notes given at the 43rd Saas Fee Advanced School

http://arxiv.org/pdf/1412.5182

The Spatial Structure of Young Stellar Clusters

Michael Kuhn



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Ph.D dissertation directed by: Eric Feigelson and Konstantin Getman

Ph.D degree awarded: August 2014

Star formation is an extremely active area of astronomical research, and young stellar clusters in our Galaxy offer a useful laboratory where star-formation processes can be studied. Young stars form from the the gravitational collapse of molecular clouds that have a hierarchical spatial structure. This leads to stars forming in clustered environments, often with thousands of other young stars in environments that are strongly affected by feedback from massive O-type stars. The environments in these massive star-forming regions (MSFR) can affect how stars form and whether the young stellar clusters remain bound after star formation ends, both of which are questions that have received considerable attention from researchers.

Studies of stellar populations in Galactic MSFRs are made difficult due to large numbers of fields stars in the Galactic Plane, large areas of the sky that must be surveyed, high optical extinction from dust, and nebulosity in the the optical and infrared. The Massive Young Star-Forming Complex Study in Infrared and X-ray (MYStIX) uses multiwavelength observations to overcome some of these difficulties, providing some of the most complete, clean membership lists for 20 MSFRs within 3.6 kpc of the Sun. I described X-ray catalogs and mid-infrared catalogs that were used in this survey.

The spatial distribution of young stars in 17 MYStIX regions are used to probe the origin and dynamics of the young stellar clusters. Intrinsic stellar surface-density maps are made for each region, which reveal complex structures with dense subclusters. I examine in detail one of the nearest MYStIX young stellar clusters, W40 (d = 500 pc), which has properties similar to many of the subclusters in more massive and more distant star-forming regions. The cluster in W40 has a simple structure with mass segregation, indicating that it has undergone dynamical evolution, even though its young age ($\sim$0.8 Myr) is insufficient for relaxation from two-body interactions. This apparent contradiction may be evidence of more rapid dynamical evolution accelerated by the merger of subclusters.

Overall, 142 subclusters of young stars are found in the 17 MSFRs using the statistical "finite-mixture model" cluster analysis method, and the intrinsic stellar populations for these clusters are inferred using "initial mass functions" and "X-ray luminosity functions." Four structural classes are seen in MSFR: linear chains of subclusters, clumpy structures, core-halo structures, and simple isolated clusters. The subclusters do follow the structure of the molecular clouds, but do not appear to be coeval with each other. There is strong evidence in the subcluster properties for gas expulsion and subcluster expansion (e.g., the density vs. radius and age vs. radius relations), and evidence that is consistent with subcluster mergers (e.g., the ellipticity distribution and the number vs. density relation).

The cluster analysis provides evidence to support hierarchical models of stellar cluster formation, which have been theorized to explain mass segregation and dynamical relaxation in very young clusters. The $\sim$1 Myr age spreads in the subclusters of a MSFR appear to require slower star-formation in giant molecular clouds with continually driven turbulence, rather than clouds with rapidly decaying turbulence. And, the diverse range of stellar surface density environment in MSFRs will have implications for models of cluster survival after gas removal.

http://dfa.uv.cl/~mkuhn/THESIS/thesis.pdf

Outflows from Young Stellar Objects: The Case of DG Tauri

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Ph.D dissertation directed by: Raquel Salmeron, Peter McGregor, Geoff Bicknell

Ph.D degree awarded: October 2014

Protostellar jets and winds play a crucial role in the dynamics and evolution of the star-formation process. They may effectively regulate mass accretion by removing angular momentum from the circumstellar disc. Despite their importance, the physical processes driving the outflow phenomena remain poorly understood. This thesis presents a consistent model for the outflow structure and dynamics of the young stellar object DG Tauri, using data of unprecedented spatial and spectral resolution from the Near-infrared Integral Field Spectrograph on Gemini North.

The approaching outflow shows two components in [Fe II] 1.644 μm emission. A stationary recollimation shock is observed in the high-velocity jet, in agreement with previous X-ray and FUV observations. The pre-shock jet velocity, and inferred jet launch point (400–700 km s^{-1} and 0.02–0.07 AU, respectively), are significantly different from previous estimates. Jet 'acceleration' beyond the shock is interpreted as intrinsic velocity variability. Careful analysis reveals no evidence of jet rotation, contrary to previous work. A wide-angle, low-velocity blueshifted molecular outflow is observed in H_2 1-0 S(1) 2.1218 μm emission. Both outflows are consistent with a magnetocentrifugal disc wind origin, although an X-wind origin for the jet cannot be excluded.

The lower-velocity [Fe II] component surrounds the jet, and is interpreted as a turbulent mixing layer generated by lateral jet entrainment of molecular wind material. An analytical model of an entrainment layer is constructed, based on Riemann decomposition of directly observable outflow parameters. The model reproduces the velocity field of the entrained material without invoking an arbitrary 'entrainment efficiency' parameter. The luminosity and mass entrainment rate estimated using the model are in agreement with observations. Such lateral entrainment requires a magnetic field strength of order a few mG at hundreds of AU above the disc surface; independent arguments are advanced to support this conclusion.

The receding outflow of DG Tau takes on a bubble-shaped morphology. Kinetic models indicate this structure is a quasi-static bubble with an internal velocity field describing expansion. It is proposed that this bubble forms because the receding counterjet from DG Tau is obstructed by a clumpy ambient medium. There is evidence of interaction between the counterjet and ambient material, which is attributed to the large molecular envelope around the DG Tau system. An analytical model of a momentum-driven bubble is shown to be consistent with observations. It is concluded that the bipolar outflow from DG Tau is intrinsically symmetric; the observed asymmetries are due to environmental effects.

The observational interpretations and comprehensive modelling of the DG Tau outflows presented in this thesis constitute a significant step forward in gaining a full physical understanding of how stars accrete their mass. The complex nature of the approaching jet provides the first clear indications of the diverse phenomena associated with protostellar mass loss. The different morphology of the receding outflow has highlighted the role of environmental factors in defining outflow characteristics. Together this work presents a new and more detailed view of the complex mechanisms associated with the formation of a low-mass star.

http://hdl.handle.net/1885/12375

New Jobs

Postdoctoral Position in Disks around Low-Mass Pre-Main Sequence Stars

The protoplanetary disks group at Boston University (BU) is searching for a postdoctoral associate who will be an integral member of our team and will work closely with Prof. Catherine Espaillat. The postdoctoral associate will lead projects on disks around low-mass pre-main sequence stars. Preference will be given to applicants who have previous experience with optical/IR/sub-mm data, mass accretion in T Tauri stars, and/or disk structure modeling.

The successful candidate will receive mentoring, career development, and networking opportunities that include advising undergraduates, interacting with faculty, students and researchers at BU and other Boston-area institutions, traveling to conferences, and organizing seminars.

The postdoctoral associate will also have access to all of the BU facilities, including the 4.3m Discovery Channel Telescope and 1.8m Perkins Telescope at Lowell Observatory.

The deadline for applications is Feb 1st. Applicants should email a single PDF file that includes a two-page statement explaining their interest and qualifications for the position, a current CV, and list of publications. Applicants should also request for 3 letters of recommendation to be sent directly from the writers by the deadline.

Email questions and application materials to Prof. Catherine Espaillat: cce@bu.edu

Research Fellow in Star Formation–University of St. Andrews

The School of Physics & Astronomy at the University of St. Andrews (Scotland) is seeking an ambitious Research Fellow to work on observational and modelling studies of the formation of massive stars and star clusters.

Applications are invited for an active researcher in the area of star formation, including astrochemistry. The fellow will work with Dr. Claudia Cyganowski and collaborators on high-resolution (sub)millimetre and radio-wavelength observations of massive star-forming regions (including Submillimeter Array, Karl G. Jansky Very Large Array, and ALMA data). The project will include generating simulated line and continuum observations from numerical models to compare with the observational data. Candidates with experience in (sub)millimetre interferometric data analysis, astrochemistry, and/or radiative transfer modelling are encouraged to apply.

The School of Physics & Astronomy offers a young, vibrant and modern work environment. Astrophysics research in St. Andrews combines theoretical, numerical and observational research in star formation, protoplanetary discs, extrasolar planets, stellar magnetic activity, star-planet interaction, gravitational lensing, active galactic nuclei, galaxy dynamics and cosmology.

The successful candidate should have a PhD in astronomy, astrophysics, or a closely related field by the appointment start date, with experience in radio/(sub)millimetre interferometry and/or astrochemical or radiative transfer modelling. Possible start dates are from April to September 2015. The appointment is in collaboration with Dr Claudia Cyganowski and Prof Ian Bonnell, funded by an STFC consolidated grant with funds for high performance computing and travel.

The post will be for 2 years in the first instance, but may be extended for up to 1 additional year subject to performance and funding. Informal enquiries to Claudia Cyganowski, e-mail: cc243@st-andrews.ac.uk

Candidates should attach a CV, publication list, and a brief statement of research experience and interests, and arrange for three letters of reference to be provided.

Web site for application submission: http://www.vacancies.st-andrews.ac.uk/welcome.aspx (search for job reference number SB1600)

Closing Date: 15 January 2015 – Interview Date: end January 2015

Meetings

Icy Grain Chemistry for Formation of Complex Organic Molecules: From Molecular Clouds to Protoplanetary Disks, Comets and Meteorites

March 5 - 7, 2015 at Tokyo Institute of Technology, Japan

http://www.geo.titech.ac.jp/lab/nomura/grain_chem/index.html

Abstract Submission Deadline : January 30, 2015

Thanks to development of infrared and mm/submm instruments, more than 170 molecules have been detected in the interstellar medium (ISM). Complexity of the detected molecules is increasing, and now ALMA (Atacama Large Millimeter/submillimeter Array) is challenging to detect amino acids in the ISM. On the other hand, amino acids have been discovered in comets and meteorites in our Solar System, and it is an open question how the complex organic molecules in our Solar System have been formed from the molecules found in the ISM.

Formation processes of complex organic molecules in space are not understood very well, but grain surface chemistry is thought to play an important role. Modelling grain surface chemistry has been developed for decades, but it still contains many uncertainties due to difficulty in laboratory experiments and theoretical calculations.

In this workshop we would like to discuss how we can develop chemical reaction network of grain surface reactions/icy mantle reactions based on laboratory experiments and theoretical calculations of basic processes. We aim to understand formation processes of complex organic molecules/ prebiotic molecules found in comets and meteorites through chemical reactions in protoplanetary disks and molecular clouds.

We look forward to fruitful discussions with participants working on laboratory experiments, theoretical calculations of basic processes and chemical reaction network, astronomical observations of complex organic molecules, and wide range of fields.

INVITED SPEAKERS

Yuri Aikawa (Kobe University, Japan)
Steven Charnley (NASA Goddard, USA)
Jim Cleaves (ELSI, TITECH, Japan)
Robin Garrod (Cornell University, USA)
Eric Herbst (University of Virginia, USA)
Kensei Kobayashi (Yokohama National Univ., Japan)
Brett McGuire (NRAO/Caltech, USA)
Tom Millar (Queen's University Belfast, UK)
Masatoshi Ohishi (NAOJ, Japan)
W.M.C. Sameera (Fukui Institute for Fundamental Chemistry, Kyoto University, Japan)
Patrice Theule (Aix-Marseille University, France)
Catherine Walsh (Leiden Observatory, Netherlands)
Naoki Watanabe (Hokkaido University, Japan)

SOC

Masatoshi Ohishi (NAOJ), Shigeru Ida (ELSI, TITECH), Yuri Aikawa (Kobe Univ.), Hideko Nomura (TITECH)

30 YEARS OF PHOTODISSOCIATION REGIONS:
A Symposium to Honor David Hollenbach's Lifetime in Science

Dear colleagues,

We are happy to announce this conference which will be held **June 28 to July 3rd, 2015 at Asilomar, California.**

The goal of this meeting is to overview the state of the art in theoretical PDR studies, to review the processes that control the physical and chemical conditions in PDRs and their emission characteristics, to compare and contrast these models with recent observations of PDRs obtained with the Spitzer Space Telescope, the Herschel Space Observatory, the Stratospheric Observatory For Infrared Astronomy, and the Atacama Large Millimeter Array, to connect studies of dense PDRs in regions of star formation to the studies of the evolution of the interstellar medium of galaxies over the history of the Universe, and to link and compare and contrast studies of PDRs to those of regions dominated by X-rays, by turbulence, by shocks, and by cosmic rays. In addition, we take this occasion to celebrate the contributions to this field of one of the pioneers, David Hollenbach.

The scientific topics of this meeting include:

- The Physics and Chemistry of PDRs,
- Models of PDRs,
- Observations PDRs in the galactic environment,
- PDRs & star and planet formation,
- PDRs & the ISM of galaxies, and
- PDRs in starburst, (U)LIRG, and high-z environments.

The format of the meeting will consist of invited reviews, invited talks, contributed papers, and poster papers. A list of invited speakers is available on the website.

VENUE: The Asilomar conference center is a California State Park (`http://www.visitasilomar.com`) beautifully situated on the coast of the Monterey peninsula in a very quiet and serene setting that we hope will be very conducive to a highly interactive meeting.

SOFIA GRANT: SOFIA has generously provided support for deserving students to defer their room and board during the meeting. Students who wish to be considered for a SOFIA travel grant have to send a letter of motivation plus a supporting letter from their supervisor. Details can be found on the website.

REGISTRATION: Registration is now open. Early registration is encouraged, as the number of participants will be limited to approximately 150.

IMPORTANT DATES: Registration and Abstract submission deadline: April 2nd, 2015
Student grant requests: February 20th, 2015. See the website for details.

WEBSITE: For more information, visit our website:

http://pdr30.strw.leidenuniv.nl

We are looking forward to an exciting meeting and hope to welcome you in Asilomar,

On behalf of the Scientific Organizing Committee,

Margaret Meixner & Xander Tielens

This is the second announcement for the STScI mini-workshop

The Stellar IMF at Low Masses: A Critical Look at Variations and Environmental Dependencies

Baltimore, MD, during June 29 - July 1, 2015

Pre-registration and abstract submission is now open. The workshop will include a combination of Invited Talks, Contributed Talks, and Posters. To help create a collaborative and engaging atmosphere, the attendance will be limited to 60-70 participants. The abstract submission deadline is February 6, 2015.

Detailed information is available at: http://www.stsci.edu/institute/conference/stellar-imf/

RATIONALE OF THE WORKSHOP

The shape of the stellar initial mass function (IMF) is one of the main uncertainties in our understanding of star formation, i.e., the conversion of gas into stars over cosmic time. It is usually assumed that the IMF in external galaxies is the same as in the disk of the Milky Way, where most studies of resolved stellar populations showed the IMF to be 'universal'.

However, the "universality" of the stellar IMF has recently been challenged: kinematics from integral-field spectroscopy of nearby galaxies as well as line strength studies of molecular features in spectra of early-type galaxies have shown evidence for a steepening of the low-mass IMF with increasing galaxy velocity dispersion. Deep star count studies in nearby dwarf galaxies seem to corroborate these findings. However, alternative explanations for the spectroscopic evidence have also started to appear in the literature.

A non-universal IMF, if confirmed, would have important implications regarding our understanding of galaxy evolution. The main purpose of this workshop is to have a critical look at current and new evidence for variations of the IMF at sub-solar stellar masses. Recent observational and theoretical insights will be presented to evaluate whether and how the IMF may vary across different environments. Emphasis will be given to the role of future observing facilities in constraining the theoretical scenarios.

We envisage covering the following general topics during this workshop:

- Uniformity of IMF in the Milky Way
- IMF theory and simulations of the low-mass end of the IMF
- Insights from molecular cloud core mass function studies
- MFs from recent deep star count studies in the local group (e.g., Galactic bulge, local group dwarf galaxies)
- Evidence for environmentally dependent IMF variations from integrated-light spectroscopy of external galaxies
- Dark matter content vs. IMF variations
- Alternative explanations for environmentally dependent variations of spectral features
- Impact of future observing facilities

The final talk of this workshop will be in the form of a special STScI colloquium on the topic of the workshop, to be held at 3:30 in the Bahcall auditorium, open to the whole STScI/JHU community. The speaker will be Marla Geha of Yale University. All the workshop participants are invited to stay at STScI after the formal conclusion of the workshop to attend this talk.

INVITED REVIEW SPEAKERS: Nate Bastian (Liverpool John Moores University), Mark Krumholtz (U.C. Santa Cruz), Michele Cappellari (University of Oxford), Charlie Conroy (Harvard University), Marla Geha (Yale University).

SCIENTIFIC ORGANIZING COMMITTEE: Paul Goudfrooij (STScI; Chair), Tom Brown (STScI), Annalisa Calamida (STScI), Mario Gennaro (STScI), Jason Kalirai (STScI), Janice Lee (STScI), Stella Offner (UMass Amherst), Rosemary Wyse (JHU)

IMPORTANT DATES:
Feb 06, 2015: Pre-registration and Abstract submission deadline
Mar 10, 2015: Notification of talk/poster presentations, full registration to open
May 29, 2015: Registration fee payment deadline
Jun 28, 2015: Opening Reception

For any questions, please email IMF2015@stsci.edu.

Summary of Upcoming Meetings

Icy Grain Chemistry for Formation of Complex Organic Molecules:
From Molecular Clouds to Protoplanetary Disks, Comets and Meteorites
5 - 7 March 2015 Tokyo Institute of Technology, Japan
http://www.geo.titech.ac.jp/lab/nomura/grain_chem/index.html

45th "Saas-Fee Advanced Course":
From Protoplanetary Disks to Planet Formation
15-20 March 2015, Switzerland
http://isdc.unige.ch/sf2015

The Soul of Massive Star Formation
15 - 20 March 2015 Puerto Varas, Chile
http://www.das.uchile.cl/msf2015/

Star and Planet Formation in the Southwest
23 - 27 March 2015 Oracle, Arizona, USA
https://lavinia.as.arizona.edu/~kkratter/SPF1/Home.html

Milky Way Astrophysics from Wide-Field Surveys
30 March - 1 April 2015, London, Burlington House at the RAS, UK
http://astro.kent.ac.uk/~df/gp/index.html

Cloudy Workshop
4 - 8 May 2015 Warsaw, Poland
http://cloud9.pa.uky.edu/~gary/cloudy/CloudySummerSchool/

Triple Evolution & Dynamics in Stellar and Planetary Systems
31 May - 5 June 2015 Haifa, Israel
http://trendy-triple.weebly.com

Workshop on the Formation of the Solar System II
2 - 4 June 2015 Berlin, Germany
https://indico.mpifr-bonn.mpg/FormationOfTheSolarSystem2

IGM@50: is the Intergalactic medium driving Star Formation?
8 - 12 June 2015 Abbazia di Spineto, Italy
http://www.arcetri.astro.it/igm50

30 Years of Photodissociation regions - A Symposium to honor David Hollenbach's lifetime in science
28 June - 3 July 2015
http://pdr30.strw.leidenuniv.nl

Gordon Research Conference on Origins of Solar Systems
28 June - 3 July 2015
http://www.grc.org/programs.aspx?id=12345

Disc dynamics and planet formation
29 June - 3 July 2015 Larnaka, Cyprus
http://www.star.uclan.ac.uk/discs2015

The Stellar IMF at Low Masses: A Critical Look at Variations and Environmental Dependencies
29 June - 1 July 2015 Baltimore, Maryland, USA
http://www.stsci.edu/institute/conference/stellar-imf/

From Interstellar Clouds to Star-forming Galaxies: Universal Processes?
3 - 7 August 2015 http://astronomy2015.org/symposium_315

Cosmic Dust
17 - 21 August 2015 Tokyo, Japan
https://www.cps-jp.org/~dust/

Extreme Solar Systems III
29 November - 4 December 2015 Hawaii, USA
http://ciera.northwestern.edu/Hawaii2015.php

The 19th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun
6 - 10 June 2016 Uppsala, Sweden
http://www.coolstars19.com

Other meetings: http://www1.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/meetings/

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.