THE STAR FORMATION NEWSLETTER

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

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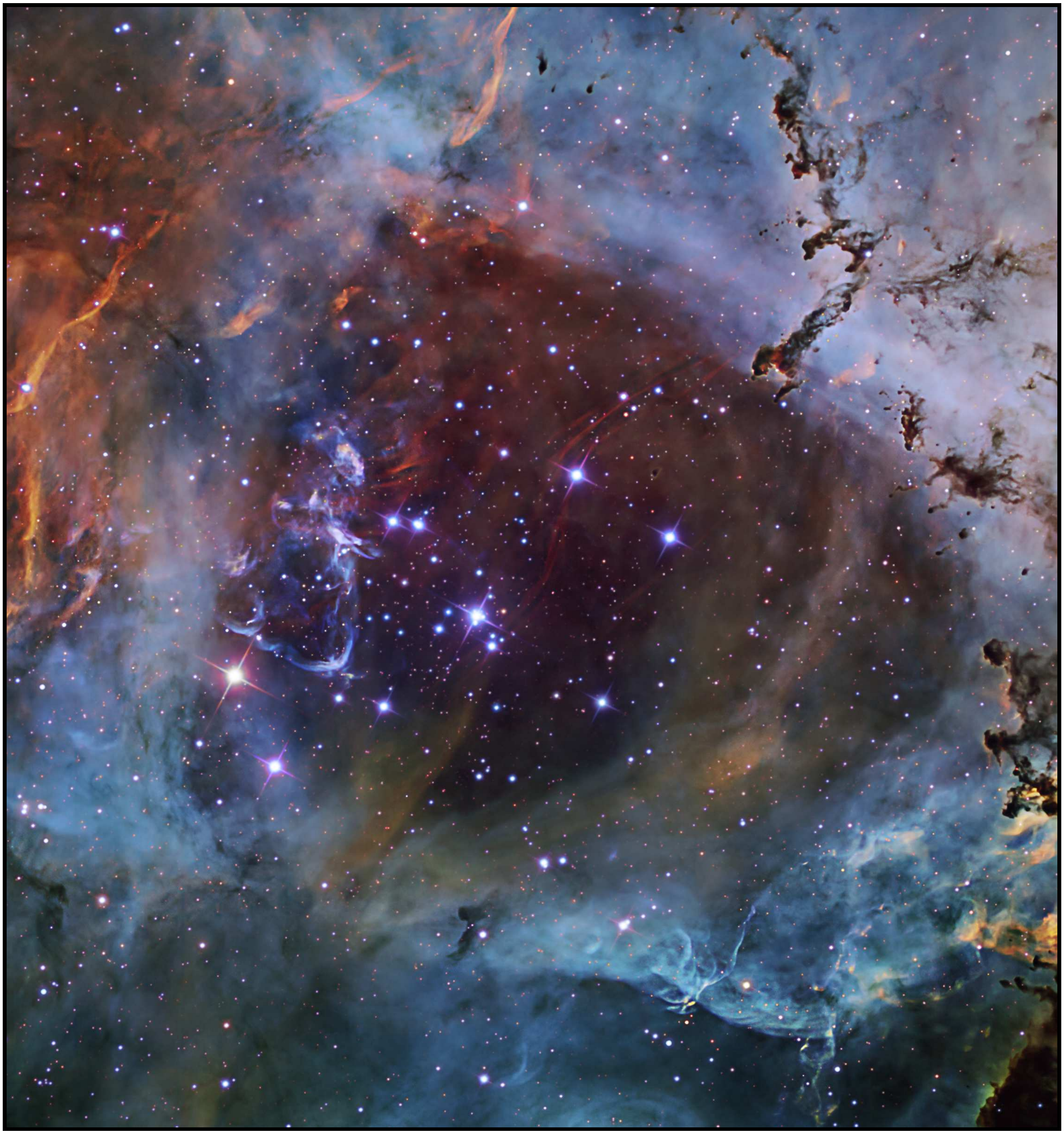

The Star Formation Newsletter

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.

Newsletter Archive

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Cover Picture

The Rosette Nebula is a large HII region in Monoceros at a distance of about 1.6 - 1.7 kpc. It is illuminated by the OB cluster NGC 2244, which contains seven O-stars, dominated by the O4V star HD 46223. The northwestern edge of the HII region contains a large complex of globules and elephant trunks.

Image courtesy Don Goldman (http://astrodonimaging.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

Susana Lizano

in conversation with Bo Reipurth

Q: *In 1987, Frank Shu, Fred Adams, and you published the Annual Reviews article 'Star Formation in Molecular Clouds - Observation and Theory', which with 2000 citations is perhaps the most cited paper on star formation. How did that come about?*

A: When we were graduate students in Berkeley, one day Frank called Fred and me into his office and invited us to write the review with him! Frank has always been very generous, especially with his students. At the time I was working on my thesis about the condensation of dense cores in molecular clouds by ambipolar diffusion and Fred was working on the SEDs of YSOs at different stages of their evolution (Class I, II and III). Frank asked each of us to focus on different parts of the subject and told us we would meet again in a couple of months to discuss this material. Needless to say that in a short time I read many papers to learn as much as possible in order to get a broader understanding of molecular clouds. Frank has always had a profound knowledge and an amazing panoramic vision; for me it was a great experience and a privilege to participate in this project. I remember when Frank drew the picture of the four stages of star formation that was put forward for the first time. The idea of simultaneous gas accretion and ejection that seems so natural today was viewed with some skepticism at the time.

Q: *Your PhD from 1988 was a theoretical study of ambipolar diffusion of magnetic fields in molecular clouds. What were the key results?*

A: We studied the process of condensation of dense cores in molecular clouds as their magnetic field diffuses out through the process of ambipolar diffusion. We also included the effect of a logatropic pressure to support the core against gravitational collapse, so that the square of the turbulent velocity is given by $v_{turb}^2 \propto 1/\rho$, like the observed velocity dispersion in molecular clouds. In our model, the cores evolved in a cylindrical periodic gravitational potential, like that of the filaments observed in recent years, although at the time we did not have an observational support for the core separation along the filaments. These cores evolved quasi-statically towards a centrally condensed state by flux redistribution, without substantial flux loss. We concluded that the major phase of flux loss had to occur at the later stage of gravitational collapse. We found that once the cores reached densities of 3×10^4 cm^{-3} at scales of 0.05 pc, like the so-called NH_3 cores, they started to collapse dynamically to form a central protostar. The transition from a starless NH_3 core to a core with a protostar took place in a few times 10^5 years for typical cloud parameters. We also found that in cores with high turbulence, the field diffuses out to become uniform and the core would not collapse unless the turbulence decays.

Q: *Around the same time you and your collaborators used the Arecibo antenna at the 21 cm line of atomic hydrogen to detect a neutral outflow at HH 7-11. What is known about such neutral outflows today?*

A: The search for HI winds was motivated by the fact that the ionized component of jets from young stars does not have enough linear momentum to drive molecular bipolar outflows. The discovery of the HI winds with Carl Heiles, Luis Rodríguez, and several other colleagues, provided support for the current idea that the observed optical jets are partially ionized ($\sim$ 10%) with the atomic hydrogen making up the rest of the mass. Unfortunately, due to lack of sensitivity, HI winds with mass loss rates of $\sim 10^{-6}\ M_\odot \mathrm{yr}^{-1}$ have only been observed in a few sources. With the Square Kilometer Array it will be possible to reexamine this problem with high angular resolution and sensitivity to determine where the high velocity HI is located. Also, some of the lower velocity HI could be H_2 dissociated in the entrainment process expected to arise in the bipolar flows.

Q: *Back in Mexico you took a fresh look at the classical problem of photoevaporation of dense globules. What were the new insights?*

A: Together with Dave Hollenbach, Doug Johnstone, and Frank Shu we first considered the problem of the photoevaporation of disks around massive young stars to extend the compact phase of UC HII regions. Several sources in massive star forming regions seem to have the morphology and dynamics of photoevaporated disks. There is a beautiful high resolution VLA study of the source G28.20-0.04N using radio recombination lines by Martha Sewilo and collaborators that shows a rotating and expanding flow. Several authors also studied the photoevaporation of disks around low mass stars and its effect on the disk evolution. In the latter case, the photoevaporation produces mass-loss rates larger than the accretion rates which rapidly creates gaps in the disks. Some pending issues are when photoevaporation sets in and whether FUV or X-rays from the central star dominate the photoevaporation and heating in disks around low mass stars.

Q: *Over the years you have had a number of talented students. Can you summarize some key results?*

A: It has been very gratifying to work with several students. Paola D'Alessio, who sadly passed away in 2013, developed models of the vertical structure of protoplanetary disks around low mass stars. These models have been extensively used and have allowed the interpretation of a wealth of observations from these disks. Mayra Osorio studied the emission of hot molecular cores and modeled them as a massive envelope collapsing onto a massive central star. These models established the conditions for the formation of massive stars with very high mass accretion rates. Mauricio González modeled the evolution of HII regions inside these collapsing cores. Mayra Lebrón made detailed studies of ionized, neutral, and molecular gas in HII regions and their associated PDRs. These types of detailed studies are important to understand the structure and dynamics of such regions. Jorge Lugo and Martín Avalos studied the dynamics and emission of photoevaporated flows from disks around massive stars to understand observations of HCHII regions. Some of these students were jointly supervised with Jorge Cantó (Paola), Luis Rodríguez (Mayra Lebrón), and Alejandro Raga (Mauricio).

Q: *Most recently you have focused on magnetized disks. Please tell more about this.*

A: Together with Carlos Tapia, Yann Boehler, and initially with Paola D'Alessio, we have modeled the vertical structure of magnetized accretion disks that have dragged their magnetic field from the parent core during the process of star formation. In 2007, together with Frank Shu, Daniele Galli, Al Glassgold, and Pat Diamond, we studied the radial structure of this class of disks. It is now known that a large fraction of the magnetic flux has to be left behind during the collapse phase to allow the formation of centrifugally supported disks. We found that the vertical structure models set constraints on the mass-to-flux ratio in the magnetized disks because for small values of this parameter, that is, for strong fields, the magnetic compression makes the disks very thin vertically, in contrast with the aspect ratios inferred from observations. We think that these models will be useful to interpret observations of magnetized disks which should be obtained in the near future with ALMA.

Q: *Until last year you were director of the institute in Morelia, which has a strong emphasis on star formation. How is Mexican astronomy developing?*

A: Last September I finished my second term as director of the Instituto de Radioastronomía y Astrofísica (IRyA) at the campus of UNAM in the city Morelia. It was a very rewarding experience to participate in the growth and development of this institute. We have a strong group that works on observations, models, and simulations of star formation, which has created a very stimulating working environment. The development of our group, that started in 1996 and is now a strong institute with international recognition and a Ph. D. program, is an example of the vitality of Mexican astronomy. There are two other larger institutions: the Instituto de Astronomía is located in both Mexico City and Ensenada, and is in charge of the National Observatory in San Pedro Mártir, Baja California, and the Instituto Nacional de Astrofísica, Optica y Electrónica in Tonantzintla which is in charge of the Large Millimeter Telescope in Sierra Negra, Puebla. There are also smaller groups in Guanajuato, Guadalajara, Monterrey, and Sonora that have grown in the last 20 years. I think that Mexican astronomy is well known internationally, it participates in several international projects, and has collaborations with many institutions worldwide. In particular, the IRyA has a very successful group of radioastronomers with strong ties to NRAO in the USA, who participated with the USA and Canada in the highly successful VLA upgrade and is now working on the Next Generation VLA project.

Q: *Mexico appears to have a higher fraction of women in astronomy than most other countries. What accounts for that?*

A: Probably it has to do with how astronomy developed in Mexico. The first astronomer in Mexico with a Ph. D. was a woman, Paris Pishmish, who came to Mexico with her Mexican husband; this occurred at the beginning of modern Mexican astronomy in the 1950's. When I was a student, we were taught by strong, dynamic, and respected women like Paris and Silvia Torres, who is now the IAU president. We grew in that environment, our professors were fair in their treatment of both male and female students, and we did not see any difference in what women could achieve. Furthermore, up to and including my generation, all astronomers got their Ph. D. in well-known universities abroad where gender respect was the norm. Of course, when we returned to México we brought with us this attitude and nurtured it.

I just want to add that through the years I have been fortunate to work on very interesting problems in stimulating collaborations with many friends that I have mentioned before, and others I did not name, like Guido Garay, with whom I learned a great deal about massive star formation.

Abstracts of recently accepted papers

Stratified NH and ND emission in the prestellar core 16293E in L1689N

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High degrees of deuterium fractionation are commonly found in cold prestellar cores and in the envelopes around young protostars. As it brings strong constraints to chemical models, deuterium chemistry is often used to infer core history or molecule formation pathways. Whereas a large number of observations is available regarding interstellar deuterated stable molecules, relatively little is known about the deuteration of hydride radicals, as their fundamental rotational transitions are at high frequencies where the atmosphere is mostly opaque. Nitrogen hydride radicals are important species in nitrogen chemistry, as they are thought to be related to ammonia formation. Observations have shown that ammonia is strongly deuterated, with $[NH_2D]/[NH_3] \sim 10\%$. Models predict similarly high [ND]/[NH] ratios, but so far only one observational determination of this ratio is available, towards the envelope of the protostar IRAS16293−2422. In order to test model predictions, we aim here at determining [ND]/[NH] in a dense, starless core. We observed NH and ND in 16293E with the HIFI spectrometer on board the Herschel Space Observatory as part of the CHESS guaranteed time key programme, and derived the abundances of these two species using a non-LTE non-local radiative transfer model. Both NH and ND are detected in the source, with ND in emission and NH in absorption against the continuum arising from the cold dust emission. Our model shows however that the ND emission and the NH absorption originate from different layers in the cloud, as further evidenced by their different velocities. In the central region of the core, we can set a lower limit to the [ND]/[NH] ratio of ∼2%. This estimate is consistent with recent pure gas-phase models of nitrogen chemistry.

Accepted by A&A

http://arxiv.org/pdf/1512.02629

X-ray deficiency on strong accreting T Tauri stars - Comparing Orion with Taurus

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Depending on whether a T Tauri star accretes material from its circumstellar disk or not, different X-ray emission properties can be found. The accretion shocks produce cool heating of the plasma, contributing to the soft X-ray emission from the star. Using X-ray data from the Chandra Orion Ultra-deep Project and accretion rates that were obtained with the Hubble Space Telescope/WFPC2 photometric measurements in the Orion Nebula Cluster, we studied the relation between the accretion processes and the X-ray emissions of a coherent sample of T Tauri sources in the region. We performed regression and correlation analyses of our sample of T Tauri stars between the X-ray parameters, stellar properties, and the accretion measurements. We find that a clear anti-correlation is present between the residual X-ray luminosity and the accretion rates in our samples in Orion that is consistent with that found on the XMM-Newton Extended Survey of the Taurus molecular cloud (XEST) study. We provide a catalog with X-ray luminosities (corrected from distance) and accretion measurements of an Orion Nebula Cluster (ONC) T Tauri stars sample. Although Orion and Taurus display strong differences in their properties (total gas and dust mass, star density, strong irradiation from massive stars), we find that a similar relation between the residual X-ray emission and accretion rate is present in the Taurus molecular cloud and in the accreting samples from the Orion Nebula Cluster. The spread in the data suggests dependencies of the accretion rates and the X-ray luminosities other than the stellar mass, but the similarity between Orion and Taurus hints at the environment not being one of them. The anti-correlation between the residual X-ray luminosity and mass accretion rate is inherent to the T Tauri stars in general, independent of their birthplace and environment, and intrinsic to early stellar evolution.

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http://arxiv.org/pdf/1512.09027

Discovery of an L4β Candidate Member of Argus in the Planetary Mass Regime: WISE J231921.92+764544.4

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We present the discovery of a young L dwarf, WISE J231921.92+764544.4, identified by comparing the Wide-field Infrared Survey Explorer (WISE) All-Sky Catalog to the Two Micron All Sky Survey (2MASS). A medium-resolution optical spectrum provides a spectral type of L4β, with a photometric distance estimate of 26.1±4.4 pc. The red WISE $W1 - W2$ color provides additional evidence of youth, while the 2MASS $J - K_s$ color does not. WISE J231921.92+764544.4 is a candidate member of the young moving group Argus, with the space motion and position of WISE J231921.92+764544.4 giving a probability of 79% membership in Argus and a probability of 21% as a field object, based on BANYAN II. WISE J231921.92+764544.4 has a mass of 12.1±0.4 $M_{\rm Jup}$ based on membership in Argus, within the planetary mass regime.

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http://arxiv.org/pdf/1512.06524

First images of debris disks around TWA 7, TWA 25, HD 35650, and HD 377

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We present the first images of four debris disks observed in scattered light around the young (4–250 Myr old) M dwarfs TWA 7 and TWA 25, the K6 star HD 35650, and the G2 star HD 377. We obtained these images by reprocessing

archival Hubble Space Telescope NICMOS coronagraph data with modern post-processing techniques as part of the Archival Legacy Investigation of Circumstellar Environments (ALICE) program. All four disks appear faint and compact compared with other debris disks resolved in scattered light. The disks around TWA 25, HD 35650, and HD 377 appear very inclined, while TWA 7's disk is viewed nearly face-on. The surface brightness of HD 35650's disk is strongly asymmetric. These new detections raise the number of disks resolved in scattered light around M and late-K stars from one (the AU Mic system) to four. This new sample of resolved disks enables comparative studies of heretofore scarce debris disks around low-mass stars relative to solar-type stars.

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http://arxiv.org/pdf/1512.02220

Water and acetaldehyde in HH212: The first hot corino in Orion

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Aims: Using the unprecedented combination of high resolution and sensitivity offered by ALMA, we aim to investigate whether and how hot corinos, circumstellar disks, and ejected gas are related in young solar-mass protostars.
Methods: We observed CH_3CHO and deuterated water (HDO) high-excitation (E_u up to 335 K) lines towards the Sun-like protostar HH212–MM1.
Results: For the first time, we have obtained images of CH_3CHO and HDO emission in the inner $\simeq$ 100 AU of HH212. The multifrequency line analysis allows us to contrain the density ($\geq 10^7$ cm^{-3}), temperature ($\simeq$ 100 K), and CH_3CHO abundance ($\simeq$ 0.2–2 $\times 10^{-9}$) of the emitting region. The HDO profile is asymmetric at low velocities ($\leq$ 2 km s^{-1} from V_{sys}). If the HDO line is optically thick, this points to an extremely small ($\sim$ 20–40 AU) and dense ($\geq 10^9$ cm^{-3}) emitting region.
Conclusions: We report the first detection of a hot corino in Orion. The HDO asymmetric profile indicates a contribution of outflowing gas from the compact central region, possibly associated with a dense disk wind.

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http://arxiv.org/pdf/1601.00539

Fragmentation in filamentary molecular clouds

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Recent surveys of dust continuum emission at sub-mm wavelengths have shown that filamentary molecular clouds are ubiquitous along the Galactic plane. These structures are inhomogeneous, with over-densities that are sometimes associated with infrared emission and active of star formation. To investigate the connection between filaments and star formation, requires an understanding of the processes that lead to the fragmentation of filaments and a determination of the physical properties of the over-densities (clumps). In this paper, we present a multi-wavelength study of five filamentary molecular clouds, containing several clumps in different evolutionary stages of star formation. We analyse the fragmentation of the filaments and derive the physical properties of their clumps. We find that the clumps in all

filaments have a characteristic spacing consistent with the prediction of the 'sausage' instability theory, regardless of the complex morphology of the filaments or their evolutionary stage. We also find that most clumps have sufficient mass and density to form high-mass stars, supporting the idea that high-mass stars and clusters form within filaments.

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http://arxiv.org/pdf/1512.06630

Proper motions of embedded protostellar jets in Serpens

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We determine the proper motion of protostellar jets around Class 0 and Class I sources in an active star forming region in Serpens. Multi-epoch deep images in the 2.122 μm line of molecular hydrogen, v=1-0 S(1), obtained with the near-infrared instrument NOTCam on a timescale of 10 years, are used to determine the proper motion of knots and jets. K-band spectroscopy of the brighter knots is used to supply radial velocities, estimate extinction, excitation temperature, and H_2 column densities towards these knots. We measure the proper motion of 31 knots on different timescales (2, 4, 6, 8, and 10 years). The typical tangtential velocity is around 50 km/s for the 10-year baseline, but for shorter timescales, a maximum tangential velocity up to 300 km/s is found for a few knots. Based on morphology, velocity information, and the locations of known protostars, we argue for the existence of at least three partly overlapping and deeply embedded flows, one Class 0 flow and two Class I flows. The multi-epoch proper motion results indicate time-variable velocities of the knots, for the first time directly measured for a Class 0 jet. We find in general higher velocities for the Class 0 jet than for the two Class I jets. While the bolometric luminosities of the three driving sources are about equal, the derived mass flow rate $\dot{\mathrm{M}}_{\mathrm{out}}$ is two orders of magnitude higher in the Class 0 flow than in the two Class I flows.

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http://arxiv.org/pdf/1601.00091

An M Dwarf Companion and Its Induced Spiral Arms in the HD 100453 Protoplanetary Disk

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Recent VLT/SPHERE near-infrared imaging observations revealed two spiral arms with a near $m = 2$ rotational symmetry in the protoplanetary disk around the $\sim$1.7 $M_\odot$ Herbig star HD 100453. A $\sim$0.3 solar mass M dwarf companion, HD 100453 B, was also identified at a projected separation of 120 AU from the primary. In this Letter, we carry out hydrodynamic and radiative transfer simulations to examine the scattered light morphology of the HD 100453 disk as perturbed by the companion on a circular and coplanar orbit. We find that the companion truncates the disk at ∼45 AU in scattered light images, and excites two spiral arms in the remaining (circumprimary) disk with a near $m = 2$ rotational symmetry. Both the truncated disk size and the morphology of the spirals are in excellent agreement with the SPHERE observations at Y, J, H, and $K1$-bands, suggesting that the M dwarf companion is indeed responsible for the observed double-spiral-arm pattern. Our model suggests that the disk is close to face on (inclination angle ∼5°), and that the entire disk-companion system rotates counterclockwise on the sky. The HD 100453 observations, along with our modeling work, demonstrate that double spiral arm patterns in near-infrared scattered light images can be generically produced by companions, and support future observations to identify the companions responsible for the arms observed in the MWC 758 and SAO 206462 systems.

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The JCMT Gould Belt Survey: Understanding the influence of molecular outflows on Gould Belt clouds

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Using JCMT Gould Belt Survey data from CO J=3–2 isotopologues, we present a meta-analysis of the outflows and energetics of star-forming regions in several Gould Belt clouds. The majority of the regions are strongly gravitationally bound. There is evidence that molecular outflows transport large quantities of momentum and energy. Outflow energies are at least 20% of the total turbulent kinetic energies in all of the regions studied and greater than the turbulent energy in half of the regions. However, we find no evidence that outflows increase levels of turbulence, and there is no correlation between the outflow and turbulent energies. Even though outflows in some regions contribute significantly to maintaining turbulence levels against dissipation, this relies on outflows efficiently coupling to bulk motions. Other mechanisms (e.g. supernovae) must be the main drivers of turbulence in most if not all of these regions.

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http://arxiv.org/pdf/1512.04813

On the universality of interstellar filaments: theory meets simulations and observations

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Filaments are ubiquitous in the universe. Recent observations have revealed that stars and star clusters form preferentially along dense filaments. Understanding the formation and properties of filaments is therefore a crucial step in understanding star formation. Here we perform three-dimensional high-resolution magnetohydrodynamical simulations that follow the evolution of molecular clouds and the formation of filaments and stars. We apply a filament detection algorithm and compare simulations with different combinations of physical ingredients: gravity, turbulence, magnetic fields and jet/outflow feedback. We find that gravity-only simulations produce significantly narrower filament profiles than observed, while simulations that include turbulence produce realistic filament properties. For these turbulence simulations, we find a remarkably universal filament width of $0.10 \pm 0.02\,\mathrm{pc}$, which is independent of the star formation history of the clouds. We derive a theoretical model that provides a physical explanation for this characteristic filament width, based on the sonic scale (λ_{sonic}) of molecular cloud turbulence. Our derivation provides λ_{sonic} as a function of the cloud diameter L, the velocity dispersion σ_v, the gas sound speed c_s, and the ratio of thermal to magnetic pressure, plasma β. For typical cloud conditions in the Milky Way spiral arms, we find $\lambda_{\mathrm{sonic}} = 0.04$–$0.16\,\mathrm{pc}$,

in excellent agreement with the filament width of 0.05–0.15 pc from observations. Consistent with the theoretical model assumptions, we find that the velocity dispersion inside the filaments is subsonic and supersonic outside. We further explain the observed $p = 2$ scaling of the filament density profile, $\rho \propto r^{-p}$ with the collision of two planar shocks forming a filament at their intersection.

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The evolution of surface magnetic fields in young solar-type stars - I. The first 250 Myr

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The surface rotation rates of young solar-type stars vary rapidly with age from the end of the pre-main sequence through the early main sequence. Important changes in the dynamos operating in these stars may result from this evolution, which should be observable in their surface magnetic fields. Here we present a study aimed at observing the evolution of these magnetic fields through this critical time period. We observed stars in open clusters and stellar associations of known ages, and used Zeeman Doppler Imaging to characterize their complex magnetic large-scale fields. Presented here are results for 15 stars, from 5 associations, with ages from 20 to 250 Myr, masses from 0.7 to 1.2 $M_{\odot}$, and rotation periods from 0.4 to 6 days. We find complex large-scale magnetic field geometries, with global average strengths from 14 to 140 G. There is a clear trend towards decreasing average large-scale magnetic field strength with age, and a tight correlation between magnetic field strength and Rossby number. Comparing the magnetic properties of our zero-age main sequence sample to those of both younger and older stars, it appears that the magnetic evolution of solar-type stars during the pre-main sequence is primarily driven by structural changes, while it closely follows the stars' rotational evolution on the main sequence.

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The formation and dynamical evolution of young star clusters

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Recent observations have revealed a variety of young star clusters, including embedded systems, young massive clusters, and associations. We study the formation and dynamical evolution of these clusters using a combination of simulations and theoretical models. Our simulations start with a turbulent molecular cloud that collapses under its own gravity. The stars are assumed to form in the densest regions in the collapsing cloud after an initial free-fall times of the molecular cloud. The dynamical evolution of these stellar distributions are continued by means of direct N-body simulations. The molecular clouds typical for the Milky Way Galaxy tend to form embedded clusters which evolve to resemble open clusters. The associations were initially considerably more clumpy, but lost their irregularity in about a dynamical time scale due to the relaxation process. The densest molecular clouds, which are absent in the Milky Way

but are typical in starburst galaxies, form massive young star clusters. They indeed are rare in the Milky Way. Our models indicate a distinct evolutionary path from molecular clouds to open clusters and associations or to massive star clusters. The mass-radius relation for both types of evolutionary tracks excellently matches the observations. According to our calculations the time evolution of the half-mass radius for open clusters and associations follows $r_{\rm h}/{\rm pc} = 2.7(t_{\rm age}/{\rm pc})^{2/3}$, whereas for massive star clusters $r_{\rm h}/{\rm pc} = 0.34(t_{\rm age}/{\rm Myr})^{2/3}$. Both trends are consistent with the observed age-mass-radius relation for clusters in the Milky Way.

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Reconstructing the history of water ice formation from HDO/H_2O and D_2O/HDO ratios in protostellar cores

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Recent interferometer observations have found that the D_2O/HDO abundance ratio is higher than that of HDO/H_2O by about one order of magnitude in the vicinity of low-mass protostar NGC 1333-IRAS 2A, where water ice has sublimated. Previous laboratory and theoretical studies show that the D_2O/HDO ice ratio should be lower than the HDO/H_2O ice ratio, if HDO and D_2O ices are formed simultaneously with H_2O ice. In this work, we propose that the observed feature, $D_2O/HDO > HDO/H_2O$, is a natural consequence of chemical evolution in the early cold stages of low-mass star formation: 1) majority of oxygen is locked up in water ice and other molecules in molecular clouds, where water deuteration is not efficient, and 2) water ice formation continues with much reduced efficiency in cold prestellar/protostellar cores, where deuteration processes are highly enhanced due to the drop of the ortho-para ratio of H_2, the weaker UV radiation field, etc. Using a simple analytical model and gas-ice astrochemical simulations tracing the evolution from the formation of molecular clouds to protostellar cores, we show that the proposed scenario can quantitatively explain the observed HDO/H_2O and D_2O/HDO ratios. We also find that the majority of HDO and D_2O ices are likely formed in cold prestellar/protostellar cores rather than in molecular clouds, where the majority of H_2O ice is formed. This work demonstrates the power of the combination of the HDO/H_2O and D_2O/HDO ratios as a tool to reveal the past history of water ice formation in the early cold stages of star formation and when the enrichment of deuterium in the bulk of water occurred. Further observations are needed to explore if the relation, $D_2O/HDO > HDO/H_2O$, is common in low-mass protostellar sources.

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The abundance of ^{26}Al-rich planetary systems in the Galaxy

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One of the most puzzling properties of the solar system is the high abundance at its birth of ^{26}Al, a short-lived radionuclide with a mean life of 1 Myr. Now decayed, it has left its imprint in primitive meteoritic solids. The origin of ^{26}Al in the early solar system has been debated for decades and strongly constrains the astrophysical context of the Sun and planets formation. We show that, according to the present understanding of star-formation mechanisms, it is very unlikely that a nearby supernova has delivered ^{26}Al into the nascent solar system. A more promising model is the one whereby the Sun formed in a wind-enriched, ^{26}Al-rich dense shell surrounding a massive star ($M > 32\ M_\odot$). We calculate that the probability of any given star in the Galaxy being born in such a setting, corresponding to a well-known mode of star formation, is of the order of 1%. It means that our solar system, though not the rule, is relatively common and that many exo-planetary systems in the Galaxy might exhibit comparable enrichments in ^{26}Al.

Such enrichments played an important role in the early evolution of planets because ^{26}Al is the main heat source for planetary embryos.

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The Musca cloud: a 6 pc-long velocity-coherent, sonic filament

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Filaments play a key role in the molecular clouds' evolution, but their internal dynamical properties remain poorly characterized. To further explore the physical state of these structures, we have investigated the kinematic properties of the Musca cloud. We have sampled the main axis of this filamentary cloud in ^{13}CO and C^{18}O (2–1) lines using APEX observations. The different line profiles in Musca shows that this cloud presents a continuous and quiescent velocity field along its $\sim$ 6.5 pc of length. With an internal gas kinematics dominated by thermal motions (i.e. $\sigma_{NT}/c_s \lesssim 1$) and large-scale velocity gradients, these results reveal Musca as the longest velocity-coherent, sonic-like object identified so far in the ISM. The (tran-)sonic properties of Musca present a clear departure from the predicted supersonic velocity dispersions expected in the Larson's velocity dispersion-size relationship, and constitute the first observational evidence of a filament fully decoupled from the turbulent regime over multi-parsec scales.

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Formation of Terrestrial Planets in Disks with Different Surface Density Profiles

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We present the results of an extensive study of the final stage of terrestrial planet formation in disks with different surface density profiles and for different orbits of Jupiter and Saturn. We carried out simulations for disk densities proportional to $r^{-0.5}$, r^{-1}, and $r^{-1.5}$, and also for partially depleted disks as in the recent model of Mars formation by Izidoro et al. (2014). The purpose of our study is to determine how the final assembly of planets and their physical properties are affected by the total mass of the disk and its radial profile. Because of the important roles of secular resonances in orbits and properties of the final planets, we studied the effects of these resonances as well. We have divided this study into two parts. In Part 1, we are interested in examining the effects of secular resonances on the formation of Mars and orbital stability of terrestrial planets. In Part 2, our goal is to determine trends that may exist between the disk surface density profile and the final properties of terrestrial planets. In the context of the depleted disk model, results show that the ν_5 resonance does not have a significant effect on the final orbits of terrestrial planets. However, ν_6 and ν_{16} resonances play important roles in clearing their affected areas ensuring that no additional mass will be scattered into the accretion zone of Mars so that it can maintain its mass and orbital stability. In Part 2, our results indicate that despite some small correlations, in general, no trend seems to exist between the disk surface density profile and the mean number of the final planets, their masses, time of formation, and distances to the central star. We present the results of our simulations and discuss their implications for the formation of Mars and other terrestrial planets, as well as the physical properties of these objects such as their masses and water contents.

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ALMA Observation of the 658 GHz Vibrationally Excited H_2O Maser in Orion KL Source I

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We present an observational study of the vibrationally excited H_2O line at 658 GHz (ν_2=1, $1_{1,0}$-$1_{0,1}$) toward Orion KL using the Atacama Large Millimeter/Submillimeter Array (ALMA). This line is clearly detected at the position of the massive protostar candidate, the Source I. The spatial structure is compact with a size of about 100 AU and is elongated along the northeast-southwest low-velocity (18 km s^{-1}) bipolar outflow traced by 22 GHz H_2O masers, SiO masers, and thermal SiO lines. A velocity gradient can be seen perpendicular to the bipolar outflow. Overall spatial and velocity structure seems analogous to that of the 321 GHz H_2O maser line previously detected with ALMA and with vibrationally excited SiO maser emission. The brightness temperature of the 658 GHz H_2O line is estimated to be higher than 2×10^4 K, implying that it is emitted via maser action. Our results suggest that the 658 GHz H_2O maser line is emitted from the base of the outflow from a rotating and expanding accretion disk as observed for the SiO masers and the 321 GHz H_2O maser. We also search for two other H_2O lines at 646 GHz ($9_{7,3}$-$8_{8,0}$ and $9_{7,2}$-$8_{8,1}$), but they are not detected in Orion KL.

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How chemistry influences cloud structure, star formation, and the IMF

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In the earliest phases of star-forming clouds, stable molecular species, such as CO, are important coolants in the gas phase. Depletion of these molecules on dust surfaces affects the thermal balance of molecular clouds and with that their whole evolution. For the first time, we study the effect of grain surface chemistry (GSC) on star formation and its impact on the initial mass function (IMF). We follow a contracting translucent cloud in which we treat the gas-grain chemical interplay in detail, including the process of freeze-out. We perform 3D hydrodynamical simulations under three different conditions, a pure gas-phase model, a freeze-out model, and a complete chemistry model. The models display different thermal evolution during cloud collapse as also indicated in Hocuk et al. (2014), but to a lesser degree because of a different dust temperature treatment, which is more accurate for cloud cores. The equation of state (EOS) of the gas becomes softer with CO freeze-out and the results show that at the onset of star formation, the cloud retains its evolution history such that the number of formed stars differ (by 7%) between the three models. While the stellar mass distribution results in a different IMF when we consider pure freeze-out, with the complete treatment of the GSC, the divergence from a pure gas-phase model is minimal. We find that the impact of freeze-out is balanced by the non-thermal processes; chemical and photodesorption. We also find an average filament width of 0.12 pc ($\pm$0.03 pc), and speculate that this may be a result from the changes in the EOS caused by the gas-dust thermal coupling. We conclude that GSC plays a big role in the chemical composition of molecular clouds and that surface processes are needed to accurately interpret observations, however, that GSC does not have a significant impact as far as star formation and the IMF is concerned.

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820 μm continuum signals dust evolution in TW Hya's disk

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Grain growth in planet-forming disks is the first step toward the formation of planets. The growth of grains and their inward drift leaves a distinct imprint on the dust surface density distribution and the resulting surface brightness profile of the thermal continuum emission. We determine the surface brightness profile of the continuum emission using resolved observations at millimeter wavelengths of the disk around TW Hya, and infer the signature of dust evolution on the surface density and dust opacity. Archival ALMA observations at 820 μm on baselines up to 410 kλ are compared to parameterized disk models to determine the surface brightness profile. Under the assumption of a constant dust opacity, a broken radial power law best describes the dust surface density with a slope of -0.53 ± 0.01 from the 4.1 au radius of the already known inner hole to a turn-over radius of 47.1 ± 0.2 au, steepening to -8.0 ± 0.1 at larger radii. The emission drops below the detection limit beyond $\sim$60 au. The shape of the dust surface density is consistent with theoretical expectations for grain growth, fragmentation, and drift, but its total dust content and its turn-over radius are too large for TW Hya's age of 8–10 Myr even when taking into account a radially varying dust opacity. Higher resolution imaging with ALMA of TW Hya and other disks is required to establish whether unseen gaps associated with, e.g., embedded planets trap grains at large radii or whether locally enhanced grain growth associated with the CO snow line explains the extent of the millimeter continuum surface brightness profile. In the latter case, population studies should reveal a correlation between the location of the CO snow line and the extent of the millimeter continuum. In the former case, and if CO freeze-out promotes planet formation, this correlation should extend to the location of gaps as well.

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Turbulent Thermal Diffusion: A Way to Concentrate Dust in Protoplanetary Discs

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Turbulence acting on mixes of gas and particles generally evenly diffuses the latter through the former. However, in the presence of background gas temperature gradients a phenomenon known as turbulent thermal diffusion appears as a particle drift velocity (rather than a diffusive term). This process moves particles from hot regions to cold ones. We rederive turbulent thermal diffusion using astrophysical language and demonstrate that it could play a major role in protoplanetary discs by concentrating particles by factors of tens. Such a concentration would set the stage for collective behavior such as the streaming instability and hence planetesimal formation.

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Detection of Sharp Symmetric Features in the Circumbinary Disk Around AK Sco

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The Search for Planets Orbiting Two Stars (SPOTS) survey aims to study the formation and distribution of planets in binary systems by detecting and characterizing circumbinary planets and their formation environments through direct imaging. With the SPHERE Extreme Adaptive Optics instrument, a good contrast can be achieved even at small (<300 mas) separations from bright stars, which enables studies of planets and disks in a separation range that was previously inaccessible. Here, we report the discovery of resolved scattered light emission from the circumbinary disk around the well-studied young double star AK Sco, at projected separations in the ∼13–40 AU range. The sharp morphology of the imaged feature is surprising, given the smooth appearance of the disk in its spectral energy distribution. We show that the observed morphology can be represented either as a highly eccentric ring around AK Sco, or as two separate spiral arms in the disk, wound in opposite directions. The relative merits of these interpretations are discussed, as well as whether these features may have been caused by one or several circumbinary planets interacting with the disk.

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Variations on Debris Disks III. Collisional Cascades and Giant Impacts in the Terrestrial Zones of Solar-type Stars

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We analyze two new sets of coagulation calculations for solid particles orbiting within the terrestrial zone of a solar-type star. In models of collisional cascades, numerical simulations demonstrate that the total mass, the mass in 1 mm and smaller particles, and the dust luminosity decline with time more rapidly than predicted by analytic models, $\propto t^{-n}$ with $n \approx$ 1.1–1.2 instead of 1. Size distributions derived from the numerical calculations follow analytic predictions at $r \lesssim 0.1$ km but are shallower than predicted at larger sizes. In simulations of planet formation, the dust luminosity declines more slowly than in pure collisional cascades, with $n \approx$ 0.5–0.8 instead of 1.1–1.2. Throughout this decline, giant impacts produce large, observable spikes in dust luminosity which last $\sim$ 0.01–0.1 Myr and recur every 1–10 Myr. If most solar-type stars have Earth mass planets with $a \lesssim$ 1–2 AU, observations of debris around 1–100 Myr stars allow interesting tests of theory. Current data preclude theories where terrestrial planets form out of 1000 km or larger planetesimals. Although the observed frequency of debris disks among $\gtrsim$ 30 Myr old stars agrees with our calculations, the observed frequency of warm debris among 5–20 Myr old stars is smaller than predicted.

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From Planetesimals to Planets in Turbulent Protoplanetary Disks I. Onset of Runaway Growth

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When planetesimals grow via collisions in a turbulent disk, stirring through density fluctuation caused by turbulence effectively increases the relative velocities between planetesimals, which suppresses the onset of runaway growth. We investigate the onset of runaway growth in a turbulent disk through simulations that calculate the mass and velocity evolution of planetesimals. When planetesimals are small, the average relative velocity between planetesimals, v_r, is much greater than their surface escape velocity, v_{esc}, so that runaway growth does not occur. As planetesimals become large via collisional growth, v_r approaches v_{esc}. When $v \approx 1.5 v_{esc}$, runaway growth of the planetesimals occurs. During the oligarchic growth subsequent to runaway growth, a small number of planetary embryos produced via runaway growth become massive through collisions with planetesimals with radii of that at the onset of runaway growth, $r_{p,run}$. We analytically derive $r_{p,run}$ as a function of the turbulent strength. Growing $\sim$10 $M_\oplus$ embryos that are suitable to become the cores of Jupiter and Saturn requires $r_{p,run} \sim 100$ km, which is similar to the proposed fossil feature in the size distribution of main belt asteroids. In contrast, the formation of Mars as quickly as suggested from Hf-W isotope studies requires small planetesimals at the onset of runaway growth. Thus, the conditions required to form Mars, Jupiter, and Saturn and the size distribution of the main-belt asteroids indicate that the turbulence increased in amplitude relative to the sound speed with increasing distance from the young Sun.

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Orbits in the T Tauri triple system observed with SPHERE

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We present new astrometric measurements of the components in the T Tauri system and derive new orbits and masses. T Tauri was observed during the science verification time of the new extreme adaptive optics facility SPHERE at the VLT. We combine the new positions with recalibrated NACO-measurements and data from the literature. Model fits for the orbits of T Tau Sa and Sb around each other and around T Tau N yield orbital elements and individual masses of the stars Sa and Sb.
Our new orbit for T Tau Sa/Sb is in good agreement with other recent results, which indicates that enough of the orbit has been observed for a reliable fit. The total mass of T Tau S is $2.65 \pm 0.11\,M_\odot$. The mass ratio $M_{Sb} : M_{Sa}$ is 0.25 ± 0.03, which yields individual masses of $M_{Sa} = 2.12 \pm 0.10\,M_\odot$ and $M_{Sb} = 0.53 \pm 0.06\,M_\odot$. If our current knowledge of the orbital motions is used to compute the position of the southern radio source in the T Tauri system, then we find no evidence of the proposed dramatic change in its path.

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Deuteration in infrared dark clouds

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Much of the dense gas in molecular clouds has a filamentary structure but the detailed structure and evolution of this gas is poorly known. We have observed 54 cores in infrared dark clouds (IRDCs) using N_2H^+ (1–0) and (3–2) to determine the kinematics of the densest material, where stars will form. We also observed N_2D^+ (3–2) towards 29 of the brightest peaks to analyse the level of deuteration which is an excellent probe of the quiescent of the early stages of star formation. There were 13 detections of N_2D^+ (3–2). This is one of the largest samples of IRDCs yet observed in these species. The deuteration ratio in these sources ranges between 0.003 and 0.14. For most of the sources the material traced by N_2D^+ and N_2H^+ (3–2) still has significant turbulent motions, however three objects show subthermal N_2D^+ velocity dispersion. Surprisingly the presence or absence of an embedded 70 μm source shows no correlation with the detection of N_2D^+ (3–2), nor does it correlate with any change in velocity dispersion or excitation temperature. Comparison with recent models of deuteration suggest evolutionary time-scales of these regions of several free-fall times or less.

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Stellar models simulating the disk-locking mechanism and the evolutionary history of the Orion Nebula cluster and NGC 2264

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Rotational evolution in young stars is described by pMS evolutionary tracks including rotation, conservation of angular momentum (AM), and simulations of disk-locking (DL). By assuming that DL is the regulation mechanism for the stellar angular velocity during the early stages of pMS, we use our models and observational data to constrain disk lifetimes ($T_{\rm disk}$) of a sample of low-mass stars in the ONC and NGC 2264. The period distributions of the ONC and NGC 2264 are bimodal and depend on the stellar mass. To follow the rotational evolution of these two clusters' stars, we generated some sets of evolutionary tracks. We assumed that the evolution of fast rotators can be modeled by considering conservation of AM during all stages and of moderate rotators by considering conservation of angular velocity during the first stages of evolution. With these models we estimate a mass and an age for all stars. For the ONC, we assume that the secondary peak in the period distribution is due to high-mass objects locked in their disks, with a locking period ($P_{\rm lock}$) of $\sim$8 days. For NGC2264 we make two hypotheses: (1) the stars in the secondary peak are locked with $P_{\rm lock}$=5 days, and (2) NGC2264 is in a later stage in the rotational evolution (this implies in a DL scenario with $P_{\rm lock}$=8 days, a $T_{\rm disk}$ of 1 Myr and, after that, constant AM evolution). We simulated the period distribution of NGC2264 when its mean age was 1 Myr. Dichotomy and bimodality appear in the simulated distribution, presenting one peak at 2 days and another one at 5–7 days, indicating that the assumption of $P_{\rm lock}$=8 days is plausible. Our hypotheses are compared with observational disk diagnoses available in the literature. DL models with $P_{\rm lock}$=8 days and 0.2 Myr $\leq T_{\rm disk} \leq$ 3 Myr are consistent with observed periods of moderate rotators of the ONC. For NGC2264, hyphotesis 2 is the more promising explanation for its period distribution.

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On the importance of scattering at 8 microns: Brighter than you think

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Context: Extinction and emission of dust models need for observational constraints to be validated. The coreshine phenomenon has already shown the importance of scattering in the 3 to 5 micron range and its ability to validate dust properties for dense cores.
Aims: We want to investigate whether scattering can also play a role at longer wavelengths and to place even tighter constraints on the dust properties. Methods. We analyze the inversion of the Spitzer 8 micron map of the dense molecular cloud L183, to examine the importance of scattering as a potential contributor to the line-of-sight extinction.
Results: The column density deduced from the inversion of the 8 micron map, when we neglect scattering, disagrees with all the other column density measurements of the same region. Modeling confirms that scattering at 8 microns is not negligible with an intensity of several hundred kJy per sr. This demonstrates the need of efficiently scattering dust grains at MIR wavelengths up to 8 microns. Coagulated aggregates are good candidates and might also explain the discrepancy at high extinction between E(J-K) et tau(9.7) toward dense molecular clouds. Further investigation requires considering efficiently scattering dust grains including ices as realistic dust models.

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Absence of Significant Cool Disks in Young Stellar Objects Exhibiting Repetitive Optical Outbursts

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We report Submillimeter Array (SMA) 1.3 mm high angular resolution observations towards the four EXor type outbursting young stellar objects (YSOs) VY Tau, V1118 Ori, V1143 Ori, and NY Ori. The data mostly show low dust masses M_{dust} in the associated circumstellar disks. Among the sources, NY Ori possesses a relatively massive disk with $M_{dust} \sim 9 \times 10^{-4}\ M_{\odot}$. V1118 Ori has a marginal detection equivalent to $M_{dust} \sim 6 \times 10^{-5}\ M_{\odot}$. V1143 Ori has a non-detection also equivalent to $M_{dust} < 6 \times 10^{-5}\ M_{\odot}$. For the nearest source VY Tau, we get a surprising non-detection which provides a stringent upper limit $M_{dust} < 6 \times 10^{-6}\ M_{\odot}$. We interpret our findings as suggesting that the gas and dust reservoirs that feed the short duration, repetitive optical outbursts seen in some EXors may be limited to the small scale, innermost region of their circumstellar disks. This hot dust may have escaped our detection limits. Follow-up, more sensitive millimeter observations are needed to improve our understanding of the triggering mechanisms of EXor type outbursts.

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The Role of Discs in the Collapse and Fragmentation of Prestellar Cores

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Disc fragmentation provides an important mechanism for producing low mass stars in prestellar cores. Here, we describe Smoothed Particle Hydrodynamics simulations which show how populations of prestellar cores evolve into stars. We find the observed masses and multiplicities of stars can be recovered under certain conditions.
First, protostellar feedback from a star must be episodic. The continuous accretion of disc material on to a central protostar results in local temperatures which are too high for disc fragmentation. If, however, the accretion occurs in intense outbursts, separated by a downtime of $\sim 10^4$ years, gravitational instabilities can develop and the disc can fragment.
Second, a significant amount of the cores' internal kinetic energy should be in solenoidal turbulent modes. Cores with less than a third of their kinetic energy in solenoidal modes have insufficient angular momentum to form fragmenting discs. In the absence of discs, cores can fragment but results in a top heavy distribution of masses with very few low mass objects.

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Properties of dwarf stars in Cygnus OB2

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We present the results of investigation of five stars, originally classified as dwarfs, belonging to Cyg OB2 association, their stellar and wind properties. Using both TLUSTY and CMFGEN codes we derived effective temperatures, surface gravities, chemical abundances, mass-loss rates and projected rotation velocities. Due to the fact that distance to the stars is well known, we were able to estimate their luminosities. Using evolutionary models we estimated the ages of these sample stars and find that lower mass ones — MT282 and MT343 —- belong to older population of the association. Their ages are greater than 10 Myr. The ages of three other stars — MT317, MT299, MT259 — are between 4-6 Myr.

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VISION - Vienna survey in Orion I. VISTA Orion A Survey

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Orion A hosts the nearest massive star factory, thus offering a unique opportunity to resolve the processes connected with the formation of both low- and high-mass stars. Here we present the most detailed and sensitive near-infrared (NIR) observations of the entire molecular cloud to date. With the unique combination of high image quality, survey coverage, and sensitivity, our NIR survey of Orion A aims at establishing a solid empirical foundation for further studies of this important cloud. In this first paper we present the observations, data reduction, and source catalog generation. To demonstrate the data quality, we present a first application of our catalog to estimate the number of stars currently forming inside Orion A and to verify the existence of a more evolved young foreground population. We used the European Southern Observatory's (ESO) Visible and Infrared Survey Telescope for Astronomy (VISTA) to survey the entire Orion A molecular cloud in the NIR J, H, and! K_S bands, covering a total of $\sim$18.3 deg^2. We implemented all data reduction recipes independently of the ESO pipeline. Estimates of the young populations toward Orion A are derived via the K_S-band luminosity function. Our catalog (799995 sources) increases the source counts compared to the Two Micron All Sky Survey by about an order of magnitude. The 90% completeness limits are 20.4, 19.9, and 19.0 mag in J, H, and K_S, respectively. The reduced images have 20% better resolution on average compared to pipeline products. We find between 2300 and 3000 embedded objects in Orion A and confirm that there is an extended foreground population above the Galactic field, in agreement with previous work. The Orion A VISTA catalog represents the most detailed NIR view of the nearest massive star-forming region and provides a fundamental basis for future studies of star formation processes toward Orion.

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http://homepage.univie.ac.at/stefan.meingast/vision.pdf

Physical parameters and long-term photometric variability of V1481 Ori, a SB2 member of Orion Nebula Cluster with an accreting component

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We present the results of our analysis on V1481 Ori (JW 239), a young SB2 in the Orion Nebula Cluster with a circumbinary disc accreting on the lower-mass component. The analysis is based on high-resolution spectroscopic data and high-quality photometric time series about 20-yr long. Thanks to the spectroscopy, we confirm the binary nature of this system consisting of M3 + M4 components and derive the mass ratio $M_{\rm B}/M_{\rm A} = 0.54$, a variable luminosity ratio $L_{\rm B}/L_{\rm A} = 0.68$–$0.94$, and an orbital period $P_{\rm orb} = 4.433$d. The photometric data allowed us to measure the rotation periods of the two components $P_{\rm phot} = 4.4351$d and they are found to be synchronized with the orbital period. The simultaneous modeling of V-, I-band, and radial velocity curves in the 2005 season suggests that the variability is dominated by one hot spot on the secondary component covering at least about 3.5% of the stellar surface and about 420K hotter than the unperturbed photosphere. Such a spot may originate from the material of the circumbinary disc accreting onto the secondary component. We also detect an apparent 6-yr periodic variation in the position of this hot spot, which is inferred from the phase migration of the light curve maximum, which we interpret as due to either the presence of surface differential rotation as large as 0.065%, a value compatible with the fully convective components, or to a periodic exchange of angular momentum between the disc and the star, which implies a minimum magnetic field strength of 650G at the stellar surface.

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Deuterium Fractionation in the Ophiuchus Molecular Cloud

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Context: In cold ($T < 25\,\mathrm{K}$) and dense ($n_H > 10^4\,\mathrm{cm}^{-3}$) interstellar clouds, molecules like CO are significantly frozen onto dust grain surfaces. Deuterium fractionation is known to be very efficient in these conditions as CO limits the abundance of H_3^+, the starting point of deuterium chemistry. In particular, N_2D^+ is an excellent tracer of dense and cold gas in star forming regions.
Aims: We measure the deuterium fraction, R_D, and the CO-depletion factor, f_d, toward a number of starless and protostellar cores in the L1688 region of the Ophiuchus molecular cloud complex and search for variations based upon environmental differences across L1688. The kinematic properties of the dense gas traced by the N_2H^+ and N_2D^+ (1–0) lines are also discussed.
Methods: R_D has been measured via observations of the J = 1–0 transition of N_2H^+ and N_2D^+ toward 33 dense cores in different regions of L1688. f_d estimates have been done using $C^{17}O$(1–0) and 850 μm dust continuum emission from the SCUBA survey. All line observations were carried out with the IRAM 30 meter antenna.
Results: The dense cores show large (≃2–40%) deuterium fractions, with significant variations between the subregions of L1688. The CO-depletion factor also varies from one region to another (between ≃1 and 7). Two different correlations are found between deuterium fraction and CO-depletion factor: cores in regions A, B2 and I show increasing R_D with increasing f_d, similar to previous studies of deuterium fraction in pre-stellar cores; cores in regions B1, B1B2, C, E, F and H show a steeper R_D–f_d correlation, with large deuterium fractions occurring in fairly quiescent gas with relatively low CO freeze-out factors. These are probably recently formed, centrally concentrated starless cores which have not yet started the contraction phase toward protostellar formation. We also find that the deuterium fraction is affected by the amount of turbulence, dust temperature and distance from heating sources in all regions of L1688, although no clear trend is found.
Conclusions: The deuterium fraction and amount of CO freeze-out are sensitive to environmental conditions and their variations across L1688 show that regions of the same molecular cloud experience different dynamical, thermal and chemical histories, with consequences for the current star formation efficiency and the characteristics of future stellar systems. The large pressures present in L1688 may induce the formation of small dense starless cores, unresolved with our beam, where the R_D–f_d relation appears to deviate from that expected from chemical models. We predict that high angular resolution observations will reconcile observations with theory.

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HH 1158: The lowest luminosity externally irradiated Herbig-Haro jet

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We have identified a new externally irradiated Herbig-Haro (HH) jet, HH 1158, within ∼2 pc of the massive OB type stars in the sigma Orionis cluster. At an $L_{\mathrm{bol}} \sim 0.1 L_{\odot}$, HH 1158 is the lowest luminosity irradiated HH jet identified to date in any cluster. Results from the analysis of high-resolution optical spectra indicate asymmetries in the brightness, morphology, electron density, velocity, and the mass outflow rates for the blue and red-shifted lobes.

We constrain the position angle of the HH 1158 jet at 102°±5°. The mass outflow rate and the mean accretion rate for HH 1158 using multiple diagnostics are estimated to be (5.2±2.6) × 10^{-10} $M_\odot$ yr^{-1} and (3.0±1.0) × 10^{-10} $M_\odot$ yr^{-1}, respectively. The properties for HH 1158 are notably similar to the externally irradiated HH 444 – HH 447 jets previously identified in σ Orionis. In particular, the morphology is such that the weaker jet beam is tilted towards the massive stars, indicating a higher extent of photo-evaporation. The high value for the Hα/[SII] ratio is also consistent with the ratios measured in other irradiated jets, including HH 444 – HH 447. The presence of an extended collimated jet that is bipolar and the evidence of shocked emission knots make HH 1158 the first unique case of irradiated HH jets at the very low-luminosity end, and provides an opportunity to learn the physical properties of very faint HH jet sources.

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CHIMPS: the ^{13}CO/C^{18}O ($J = 3 \rightarrow 2$) Heterodyne Inner Milky Way Plane Survey

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We present the ^{13}CO/C^{18}O ($J = 3 \rightarrow 2$) Heterodyne Inner Milky Way Plane Survey (CHIMPS) which has been carried out using the Heterodyne Array Receiver Program on the 15 m James Clerk Maxwell Telescope (JCMT) in Hawaii. The high-resolution spectral survey currently covers $|b| \leq 0.5°$ and $28° < l < 46°$, with an angular resolution of 15 arcsec in 0.5 km s^{-1} velocity channels. The spectra have a median rms of ~ 0.6 K at this resolution, and for optically thin gas at an excitation temperature of 10 K, this sensitivity corresponds to column densities of $N_{\mathrm{H}_2} \sim 3 \times 10^{20}\,\mathrm{cm}^{-2}$ and $N_{\mathrm{H}_2} \sim 4 \times 10^{21}\,\mathrm{cm}^{-2}$ for ^{13}CO and C^{18}O, respectively. The molecular gas that CHIMPS traces is at higher column densities and is also more optically thin than in other publicly available CO surveys due to its rarer isotopologues, and thus more representative of the three-dimensional structure of the clouds. The critical density of the $J = 3 \rightarrow 2$ transition of CO is $> 10^4\,\mathrm{cm}^{-3}$ at temperatures of ≤ 20 K, and so the higher density gas associated with star formation is well traced. These data complement other existing Galactic plane surveys, especially

the JCMT Galactic Plane Survey which has similar spatial resolution and column density sensitivity, and the *Herschel* infrared Galactic Plane Survey. In this paper, we discuss the observations, data reduction and characteristics of the survey, presenting integrated emission maps for the region covered. Position velocity diagrams allow comparison with Galactic structure models of the Milky Way, and while we find good agreement with a particular four arm model, there are some significant deviations.

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The Gaia-ESO Survey: Dynamical Analysis of the L1688 region in Ophiuchus

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The Gaia ESO Public Spectroscopic Survey (GES) is providing the astronomical community with high-precision measurements of many stellar parameters including radial velocities (RVs) of stars belonging to several young clusters and star-forming regions. One of the main goals of the young cluster observations is to study of their dynamical evolution and provide insight into their future, revealing if they will eventually disperse to populate the field, rather than evolve into bound open clusters. In this paper we report the analysis of the dynamical state of L1688 in the ρ Ophiuchi molecular cloud using the dataset provided by the GES consortium. We performed the membership selection of the more than 300 objects observed. Using the presence of the lithium absorption and the location in the Hertzspung-Russell diagram, we identify 45 already known members and two new association members. We provide accurate RVs for all 47 confirmed members. A dynamical analysis, after accounting for unresolved binaries and errors, shows that the stellar surface population of L1688 has a velocity dispersion $\sigma \sim$1.14$\pm$0.35 km s^{-1} that is consistent with being in virial equilibrium and is bound with a ∼80% probability. We also find a velocity gradient in the stellar surface population of ∼1.0 km $s^{-1}pc^{-1}$ in the northwest/southeast direction, which is consistent with that found for the pre-stellar dense cores, and we discuss the possibility of sequential and triggered star formation in L1688.

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Dynamical Masses of Young Stars I: Discordant Model Ages of Upper Scorpius

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We present the results of a long term orbit monitoring program, using sparse aperture masking observations taken with NIRC2 on the Keck-II telescope, of seven G to M-type members of the Upper Scorpius subgroup of the Sco-Cen OB association. We present astrometry and derived orbital elements of the binary systems we have monitored, and also determine the age, component masses, distance and reddening for each system using the orbital solutions and multi-band photometry, including Hubble Space Telescope photometry, and a Bayesian fitting procedure. We find that the models can be forced into agreement with any individual system by assuming an age, but that age is not consistent across the mass range of our sample. The G-type binary systems in our sample have model ages of ∼11.5 Myr, which is consistent with the latest age estimates for Upper Scorpius, while the M-type binary systems have significantly younger model ages of ∼7 Myr. Based on our fits, this age discrepancy in the models corresponds to a luminosity under-prediction of 0.8–0.15 dex, or equivalently an effective temperature over-prediction of 100–300 K for M-type stars at a given premain-sequence age. We also find that the M-type binary system RXJ 1550.0−2312 has an age (∼16 Myr) and distance (∼90 pc) indicating that it is either a nearby young binary system or a member of the Upper-Centaurus-Lupus subgroup with a 57% probability of membership.

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Recurring Occultations of RW Aurigae by Coagulated Dust in the Tidally Disrupted Circumstellar Disk

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We present photometric observations of RW Aurigae, a Classical T Tauri system, that reveal two remarkable dimming events. These events are similar to that which we observed in 2010–2011, which was the first such deep dimming observed in RW Aur in a century's worth of photometric monitoring. We suggested the 2010–2011 dimming was the result of an occultation of the star by its tidally disrupted circumstellar disk. In 2012–2013, the RW Aur system dimmed by ∼0.7 mag for ∼40 days and in 2014/2015 the system dimmed by ∼2 mag for >250 days. The ingress/egress duration measurements of the more recent events agree well with those from the 2010–2011 event, providing strong evidence that the new dimmings are kinematically associated with the same occulting source. Therefore, we suggest that both the 2012–2013 and 2014–2015 dimming events, measured using data from the Kilodegree Extremely Little Telescope and

the Kutztown University Observatory, are also occultations of RW Aur A by tidally disrupted circumstellar material. Recent hydrodynamical simulations of the eccentric fly-by of RW Aur B suggest the occulting body to be a bridge of material connecting RW Aur A and B. These simulations suggest the possibility of additional occultations, supported by the observations presented in this work. The color evolution of the dimmings suggest that the tidally stripped disk material includes dust grains ranging in size from small grains at the leading edge, typical of star forming regions, to large grains, ices or pebbles producing grey or nearly grey extinction deeper within the occulting material. It is not known whether this material represents arrested planet building prior to the tidal disruption event, or perhaps accelerated planet building as a result of the disruption event, but in any case the evidence suggests the presence of advanced planet building material in the space between RW Aur A and B.

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Dust and Polycyclic Aromatic Hydrocarbon in the Pre-Transitional Disk around HD 169142

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The pre-transitional disk around the Herbig Ae star HD 169142 shows a complex structure of possible ongoing planet formation in dust thermal emission from the near infrared (IR) to millimeter wavelength range. Also, a distinct set of broad emission features at 3.3, 6.2, 7.7, 8.6, 11.3, and 12.7 μm, commonly attributed to polycyclic aromatic hydrocarbons (PAHs), are detected prominently in the HD 169142 disk. We model the spectral energy distribution (SED) as well as the PAH emission features of the HD 169142 disk simultaneously with porous dust and astronomical-PAHs taking into account the spatially resolved disk structure. Our porous dust model consisting of three distinct components that are primarily concentrated in the inner ring, middle ring, and outer disk, respectively, provides an excellent fit to the entire SED, and the PAH model closely reproduces the observed PAH features. The accretion of ice mantles onto porous dust aggregates occurs between $\sim$16 AU and 60 AU, which overlaps with the spatial extent ($\sim$50 AU) of the observed PAH emission features. Finally, we discuss the role of PAHs in the formation of planets possibly taking place in the HD 169142 system.

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Analysis of the instability due to gas-dust friction in protoplanetary discs

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We study stability of a dust layer in a gaseous disc subject to the linear axisymmetric perturbations. Instead of considering single-size particles, however, the population of dust particles is assumed to consist of two grain species. Dust grains exchange momentum with the gas via the drag force and their self-gravity is also considered. We show that the presence of two grain sizes can increase the efficiency of the linear growth of drag-driven instability in the protoplanetary discs. A second dust phase with a small mass, comparing to the first dust phase, would reduce the growth timescale even by a factor of two or more especially when its coupling to the gas is weak. It means that once a certain amount of large dust particles form, even though it is much smaller than that of small dust particles, the dust layer becomes more unstable and dust clumping are accelerated. Thus, presence of dust particles with various sizes must be considered in studies of dust clumping in protoplanetary discs where both large and small dust grains are present.

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Stable and unstable accretion in the classical T Tauri stars IM Lup and RU Lup as observed by MOST

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Results of the time variability monitoring of the two classical T Tauri stars, RU Lup and IM Lup, are presented. Three photometric data sets were utilised: (1) simultaneous (same field) MOST satellite observations over four weeks in each of the years 2012 and 2013, (2) multicolour observations at the SAAO in April – May of 2013, (3) archival V-filter ASAS data for nine seasons, 2001–2009. They were augmented by an analysis of high-resolution, public-domain VLT-UT2 UVES spectra from the years 2000 to 2012. From the MOST observations, we infer that irregular light variations of RU Lup are caused by stochastic variability of hot spots induced by unstable accretion. In contrast, the MOST light curves of IM Lup are fairly regular and modulated with a period of about 7.19–7.58 d, which is in accord with ASAS observations showing a well defined 7.247±0.026 d periodicity. We propose that this is the rotational period of IM Lup and is due to the changing visibility of two antipodal hot spots created near the stellar magnetic poles during the stable process of accretion. Re-analysis of RU Lup high-resolution spectra with the Broadening Function approach reveals signs of a large polar cold spot, which is fairly stable over 13 years. As the star rotates, the spot-induced depression of intensity in the Broadening Function profiles changes cyclically with period 3.71058 d, which was previously found by the spectral cross-correlation method.

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Implication of Formation Mechanisms of HC_5N in TMC-1 as Studied by ^{13}C Isotopic Fractionation

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We observed the $J = 9-8$ and $16-15$ rotational transitions of the normal species and five ^{13}C isotopologues of HC_5N to

study its formation mechanisms toward the cyanopolyyne peak in Taurus Molecular Cloud-1, with the 45-m radio telescope of Nobeyama Radio Observatory. We detected the five ^{13}C isotopologues with high signal-to-noise ratios between 12 and 20, as well as the normal species. The abundance ratios of the five ^{13}C isotopologues of HC_5N are found to be 1.00 : 0.97 : 1.03 : 1.05 : 1.16 (±0.19) for [$H^{13}CCCCCN$]:[$HC^{13}CCCCN$]:[$HCC^{13}CCCN$]:[$HCCC^{13}CCN$]:[$HCCCC^{13}CN$]. We do not find any significant differences among the five ^{13}C isotopologues. The averaged [HC_5N]/[^{13}C isotopologues] abundance ratio is determined to be 94 (±6), which is slightly higher than the local interstellar elemental $^{12}C/^{13}C$ ratio of $60 - 70$. Possible formation pathways are discussed on the basis of these results.

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Angular Momentum of the N2H+ Cores in the Orion A Cloud

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We have analyzed the angular momentum of the molecular cloud cores in the Orion A giant molecular cloud observed in the N_2H^+ $J = 1 \rightarrow 0$ line with the Nobeyama 45 m radio telescope. We have measured the velocity gradient using position velocity diagrams passing through core centers, and made sinusoidal fitting against the position angle. 27 out of 34 N_2H^+ cores allowed us to measure the velocity gradient without serious confusion. The derived velocity gradient ranges from 0.5 to 7.8 km s^{-1} pc^{-1}. We marginally found that the specific angular momentum J/M (against the core radius R) of the Orion N_2H^+ cores tends to be systematically larger than that of molecular cloud cores in cold dark clouds obtained by Goodman et al., in the $J/M - R$ relation. The ratio β of rotational to gravitational energy is derived to be $\beta = 10^{-2.3\pm0.7}$, and is similar to that obtained for cold dark cloud cores in a consistent definition. The large-scale rotation of the $\int$-shaped filament of the Orion A giant molecular cloud does not likely govern the core rotation at smaller scales.

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Two-level hierarchical fragmentation in the Orion Molecular Cloud 1 northern filament

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Context: The filamentary structure of molecular clouds may set important constraints on the mass distribution of stars forming within them. It is therefore important to understand which physical mechanism dominates filamentary cloud fragmentation and core formation.
Aims: Orion A is the nearest giant molecular cloud, and its so-called $\int$- shaped filament is a very active star-forming region that is a good target for such a study. We have recently reported on the collapse and fragmentation properties of the northernmost part of this structure, located ~2.4 pc north of Orion KL the Orion Molecular Cloud 3. As part of our project to study the $\int$-shaped filament, we analyze the fragmentation properties of the northern OMC1 filament (located $\lesssim$0.3 pc north of Orion KL). This filament is a dense structure previously identified by JCMT/SCUBA submillimeter continuum and VLA NH_3 observations and was shown to have fragmented into clumps. Our aim is to search for cores and young protostars embedded within OMC1 n and to study how the filament is fragmenting to form

them.
Methods: We observed OMC1North (hereafter OMC1n) with the Submillimeter Array (SMA) at 1.3mm and report on our analysis of the continuum data.
Results: We discovered 24 new compact sources, ranging in mass from 0.1 to 2.3 $M_\odot$, in size from 400 to 1300 au, and in density from 2.6×10^7 to $2.8 \times 10^6\,cm^{-3}$. The masses of these sources are similar to those of the SMA protostars in OMC 3, but their typical sizes and densities are lower by a factor of ten. Only 8% of the new sources have infrared counterparts, but there are five associated CO molecular outflows. These sources are thus likely in the Class 0 evolutionary phase but it cannot be excluded that some of the sources might still be pre-stellar cores. The spatial analysis of the protostars shows that they are divided into small groups that coincide with previously identified JCMT/SCUBA 850 μm and VLA NH_3 clumps, which are separated by a quasi-equidistant length of $\approx 30'$ (0.06 pc). This separation is dominated by the Jeans length and therefore indicates that the main physical process in the filament evolution was thermal fragmentation. Within the protostellar groups, the typical separation is $\approx 6''$ ($\sim$2500 au), which is a factor 2-3 smaller than the Jeans length of the parental clumps within which the protostars are embedded. These results point to a hierarchical (two-level) thermal fragmentation process of the OMC1 n filament.

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The VLA Nascent Disk and Multiplicity Survey of Perseus Protostars (VANDAM). II. Multiplicity of Protostars in the Perseus Molecular Cloud

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We present a multiplicity study of all known protostars (94) in the Perseus molecular cloud from a Karl G. Jansky Very Large Array (VLA) survey at Ka-band (8 mm and 1 cm) and C-band (4 cm and 6.6 cm). The observed sample has a bolometric luminosity range between 0.1 $L_\odot$ and $\sim$33 $L_\odot$, with a median of 0.7 $L_\odot$. This multiplicity study is based on the Ka-band data, having a best resolution of $\sim$0.065 arcsec (15 AU) and separations out to $\sim$43 arcsec (10000 AU) can be probed. The overall multiplicity fraction (MF) is found to be of 0.40$\pm$0.06 and the companion star fraction (CSF) is 0.71$\pm$0.06. The MF and CSF of the Class 0 protostars are 0.57$\pm$0.09 and 1.2$\pm$0.2, and the MF and CSF of Class I protostars are both 0.23$\pm$0.08. The distribution of companion separations appears bi-modal, with a peak at $\sim$75 AU and another peak at $\sim$3000 AU. Turbulent fragmentation is likely the dominant mechanism on >1000 AU scales and disk fragmentation is likely to be the dominant mechanism on <200 AU scales. Toward three Class 0 sources we find companions separated by <30 AU. These systems have the smallest separations of currently known Class 0 protostellar binary systems. Moreover, these close systems are embedded within larger (50 AU to 400 AU) structures and may be candidates for ongoing disk fragmentation.

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A Two-Temperature Model of Magnetized Protostellar Outflows

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We explore kinematics and morphologies of molecular outflows driven by young protostars using magnetohydrodynamic simulations in the context of the unified wind model of Shang et al. The model explains the observed high-velocity jet and low-velocity shell features. In this work we investigate how these characteristics are affected by the underlying temperature and magnetic field strength. We study the problem of a warm wind running into a cold ambient toroid by using a tracer field that keeps track of the wind material. While an isothermal equation of state is adopted, the effective temperature is determined locally based on the wind mass fraction. In the unified wind model, the density of the wind is cylindrically stratified and highly concentrated toward the outflow axis. Our simulations show that for a sufficiently magnetized wind, the jet identity can be well maintained even at high temperatures. However, for a high temperature wind with low magnetization, the thermal pressure of the wind gas can drive material away from the axis, making the jet less collimated as it propagates. We also study the role of the poloidal magnetic field of the toroid. It is shown that the wind-ambient interface becomes more resistant to corrugation when the poloidal field is present, and the poloidal field that bunches up within the toroid prevents the swept-up material from being compressed into a thin layer. This suggests that the ambient poloidal field may play a role in producing a smoother and thicker swept-up shell structure in the molecular outflow.

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Evolution of OH and CO-dark Molecular Gas Fraction Across a Molecular Cloud Boundary in Taurus

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We present observations of ^{12}CO J=1-0, ^{13}CO J=1-0, HI, and all four ground-state transitions of the hydroxyl (OH) radical toward a sharp boundary region of the Taurus molecular cloud. Based on a PDR model that reproduces CO and [CI] emission from the same region, we modeled the three OH transitions, 1612, 1665, 1667 MHz successfully through escape probability non-LTE radiative transfer model calculations. We could not reproduce the 1720 MHz observations, due to un-modeled pumping mechanisms, of which the most likely candidate is a C-shock. The abundance of OH and CO-dark molecular gas (DMG) are well constrained. The OH abundance [OH]/[H_2] decreases from 8×10^{-7} to 1×10^{-7} as A_v increases from 0.4 to 2.7 mag, following an empirical law

$$[\mathrm{OH}]/[\mathrm{H_2}] = 1.5\times10^{-7} + 9.0\times10^{-7}\times\exp(-A_v/0.81),$$

which is higher than PDR model predictions for low extinction regions by a factor of 80. The overabundance of OH at extinctions at or below 1 mag is likely the result of a C-shock. The dark gas fraction (DGF, defined as fraction of molecular gas without detectable CO emission) decreases from 80% to 20%, following a gaussian profile

$$\mathrm{DGF} = 0.90\times\exp(-(\tfrac{A_v-0.79}{0.71})^2).$$

This trend of the DGF is consistent with our understanding that the DGF drops at low visual extinction due to photodissociation of H_2 and drops at high visual extinction due to CO formation. The DGF peaks in the extinction range where H_2 has already formed and achieved self-shielding but ^{12}CO has not. Two narrow velocity components with a peak-to-peak spacing of ~ 1 km s^{-1} were clearly identified. Their relative intensity and variation in space and frequency suggest colliding streams or gas flows at the boundary region.

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Low-metallicity Young Clusters in the Outer Galaxy I. Sh 2-207

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To study star formation in low metallicity environments ([M/H] ~ -1 dex), we obtained deep near-infrared (NIR) images of Sh 2-207 (S207), which is an HII region in the outer Galaxy with spectroscopically determined metallicity of [O/H] $\simeq -0.8$ dex. We identified a young cluster in the western region of S207 with a limiting magnitude of $K_S = 19.0$ mag (10 σ) that corresponds to a mass detection limit of $\lesssim 0.1\,M_\odot$ and enables the comparison of star-forming properties under low metallicity with those of the solar neighborhood. From the fitting of the K-band luminosity function (KLF), the age and distance of S207 cluster are estimated at 2–3 Myr and $\sim$4 kpc, respectively. The estimated age is consistent with the suggestion of small extinctions of stars in the cluster ($A_V \sim 3$ mag) and the non-detection of molecular clouds. The reasonably good fit between observed KLF and model KLF suggests that the underlying initial mass function (IMF) of the cluster down to the detection limit is not significantly different from the typical IMFs in the solar metallicity. From the fraction of stars with NIR excesses, a low disk fraction (<10 %) in the cluster with relatively young age is suggested, as we had previously proposed.

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Abstracts of recently accepted major reviews

Planetesimals in Debris Disks

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Planetesimals form in gas-rich protoplanetary disks around young stars. However, protoplanetary disks fade in about 10 Myr. The planetesimals (and also many of the planets) left behind are too dim to study directly. Fortunately, collisions between planetesimals produce dusty debris disks. These debris disks trace the processes of terrestrial planet formation for 100 Myr and of exoplanetary system evolution out to 10 Gyr. This chapter begins with a summary of planetesimal formation as a prelude to the epoch of planetesimal destruction. Our review of debris disks covers the key issues, including dust production and dynamics, needed to understand the observations. Our discussion of extrasolar debris keeps an eye on similarities to and differences from Solar System dust.

Accepted by "Planetesimals: Early Differentiation and Consequences for Planets"

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Tales of Orion:
The interplay of gas, dust, and stars in the interstellar medium

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Ph.D degree awarded: September 2015

This thesis aims to advance our understanding of the interactions between gas, dust, and stars in the ISM, while adding new insights into the evolution of one of the best studied regions in the sky, Orion.

A chance encounter between the Orion B molecular cloud and the star cluster σ Ori sets up a champagne flow of ionized gas that entrains dust, forcing the dust to flow into the IC434 HII region. We compared observations of the region with our model that quantitatively describes the interaction of a dusty ionized flow of gas with nearby (massive) stars, where radiation pressure stalls dust and force it to flow around the star to form a *dust wave*. In this way, we are able to constrain important parameters of the dust grains entrained within the ionized gas that can not be studied using classical emission or extinction studies. Some of the results are puzzling, and contrast with other studies of interstellar dust.

Massive stars drive the evolution of the interstellar medium through their radiative and mechanical energy input. We studied the expansion of Galactic HII regions and the formation of dust waves therein. The bubbles seen in Spitzer and Herschel surveys of the Galactic plane offer a unique opportunity to study the formation of dust waves and the relative importance of stellar feedback mechanisms in relative young regions of simple geometry. Dust waves provide 1) a natural explanation for the presence of dust inside HII bubbles 2) offer a novel method to study dust in HII regions 3) and act as a probe of the radiative interaction of a massive star with its surroundings, providing direct evidence that bubbles are relieving their pressure into the interstellar medium through a champagne flow that may be a key source of turbulence, controlling the structure of the ISM on smaller scales.

The Orion-Eridanus superbubble is the prototypical superbubble due to its proximity and evolutionary state. We have performed an observational analysis of the superbubble, and the synergy of different datasets reveals an updated picture on the morphological and dynamical structure of the superbubbble, which turns out to be much larger and complex than previously thought. The evolution of the superbubble is powered through the gradual evaporation of the Orion molecular clouds, mass-loading the interior of the superbubble through destructive champagne flows and thermal evaporation of clouds embedded in the hot gas. Explosive feedback mechanisms accelerate, sweep-up, and compress these poisoned plasmas in an episodic fashion to form nested shells within the Orion-Eridanus superbubble that may cool, collapse, and fragment to form stars of their own. The shells rejuvenate the superbubble by cleansing the interior and by plastering the mass and add momentum to the outer wall, driving the further expansion of the superbubble. The cycle of mass-loading, cleansing, and star formation ceases when feedback has disrupted the molecular reservoir, from which the superbubble will disappear and merge with the ISM.

Postdoctoral position in the young research group "Reservoirs for Planetary Atmospheres" at INAF / Arcetri Astrophysical Observatory

The INAF/Arcetri Astrophysical Observatory (Florence, Italy) is seeking an enthusiastic and highly qualified post-doctoral researcher to work in the newly established young research group led by dr. Davide Fedele. The target of the group is the physical structure and chemical composition of protoplanetary disks. The main activity of the group is the analysis of infrared (VLT/CRIRES and VISIR, Herschel) and (sub-)millimetre (ALMA) observations of protoplanetary disks. The successful candidate is expected to work on ALMA observations of Herbig Ae disks.

This position is part of a SIR (http://sir.miur.it) group led by dr. Davide Fedele and financed by the Italian Ministry of Science, Research and Education. The INAF/Arcetri Astrophysical Observatory in Florence is a lively scientific environment and the SIR group of dr. Davide Fedele is embedded in the star and planet formation department which is one of the main node in Europe in the field. The successful candidate will also join the JEDI team (http://www.oa-roma.inaf.it/irgroup/JEDI/JEDI/Home.html).

The position will be for an initial period of 2 years with a possible extension of one year dependent on performance. The expected beginning of the position is May 2016, but the exact starting date is flexible. Application deadline is January 29 2016. A competitive salary of 30000,00 Euro/year is offered. Applications should comprise a cover letter, a CV including publications, a concise statement of previous research and research interests (max 2 pages), and 2 letters of recommendation. For inquires, instructions on how to apply, information about salary and benefits, please visit the webpage:

http://www.arcetri.astro.it/images/data/Concorsi/DD12016/Bando-DD1-2016-en.pdf

and contact: fedele@arcetri.astro.it

Molecular Gas in Galactic Environments
April 4-7, 2016 Omni Charlottesville Hotel, Charlottesville, Virginia

ALMA's line sensitivity and spectral grasp has resulted in the identification and imaging of more than forty molecules outside the Milky Way. The workshop focuses on the character of the molecular gas in the varied environments in which these molecules are found beyond our Galaxy. This international conference will bring together ALMA, VLA and GBT users and potential users of other upcoming facilities, such as ngVLA, JWST, and TMT to consider what capabilities or upgrades to these instruments might facilitate the study of extragalactic molecules most?

This 4-day NAASC workshop will consist of a number of invited talks to guide the discussions of relevant questions to be addressed. Contributed abstracts will be solicited, and the SOC will select a subset for oral presentations. The rest of the accepted abstracts will be posters, with 1m introductions (Flash Posters) of the posters during the meeting. Registration will include workshop materials, daily breakfast, breaks, and a welcome reception. Optional excursions and a conference dinner will also be available.

Workshop website

https://science.nrao.edu/science/meetings/2016/molecular-gas-in-galactic-environments/

Half a Decade of ALMA: Cosmic Dawns Transformed. International ALMA Meeting to be held September 20 - 23, 2016 in Indian Wells, CA, USA

The sensitivity and spectral grasp of the Atacama Large Millimeter/submillimeter Array (ALMA) have revolutionized the study of youngest structures in the Universe, from galaxy formation through the formation of stars and planets. ALMA has produced over 300 refereed papers with over 3000 citations at its four-year mark, reporting impressive and scientifically compelling results as the most sensitive and highest resolution mm/submm interferometer in the world.

One aim of the four day conference is to highlight recent ALMA results at the threshold of its fifth year of operation. Another goal is to bring together researchers from around the world to motivate collaborations for ALMA's Cycle 5. Science topics will include all fields of astronomy, from cosmology and galaxies in the distant universe, nearby galaxies and the Galactic Center, ISM and star formation in our own galaxy, astrochemistry, circumstellar disks, exoplanets, solar system, stellar evolution and the Sun.

The conference will feature invited and contributed talks as well as poster sessions. Young researchers and students are particularly encouraged to attend the meeting.

http://www.cvent.com/events/half-a-decade-of-alma-cosmic-dawns-transformed/event-summary-12c52aba23024057862

Planetary Formation session at COSPAR 2016
Istanbul, Turkey, on 30 July - 7 August 2016

The Committee on Space Research (COSPAR) will hold its 41st Scientific Assembly in Istanbul, Turkey, on 30 July - 7 August 2016. The COSPAR Scientific Assemblies supply a forum to all scientists involved in space research for the presentation of their latest scientific results, the exchange of knowledge and also the discussion of space research problems. Together with the now traditional session devoted to exoplanetary studies, event E1.21 "Exoplanets", COSPAR 2016 will also hold for the first time a session specifically dedicated to the formation and the evolution of planets and planetary systems, event B0.5 "Planetary Formation: From Dust to Giant Exoplanets". This event, currently planned to take place over two half-day sessions, is jointly organized by Commission B "Space Studies of the Earth-Moon System, Planets, and Small Bodies of the Solar System" and Commission E "Research in Astrophysics from Space".

Scientific rationale of event B0.5 "Planetary Formation: From Dust to Giant Exoplanets":

Our understanding of planetary formation as derived from the Solar System, for decades the only known example of a planetary system, has been challenged over the last twenty years by the rich diversity of discovered extrasolar planets. The Solar System, however, still represents a unique source of detailed information on the processes shaping the formation and subsequent evolution of planets, both individually and as a whole. Theoretical works on the formation and early dynamical evolution of planetary systems has helped to bridge the gap between the story told by the Solar System and that coming from the extrasolar planets, but the ever growing body of data supplied by space missions and ground-based facilities promises new challenges in the coming years. The aim of COSPAR 2016 event B0.5 "Planetary Formation: From Dust to Giant Exoplanets" is to offer to all involved communities a common space for discussing new theoretical, observational and laboratory results about the formation and evolution of planetary systems and of their formation environments, the protoplanetary disks.

Conference website: https://www.cospar-assembly.org/

Abstract submission deadline: 2016 February 12

Scientific Organizing Committee:

Diego Turrini (Main Scientific Organizer, INAF-IAPS, Italy), Sho Sasaki (Deputy Organizer, Osaka University, Japan), Francesca Altieri (INAF-IAPS, Italy), Gennaro D'Angelo (SETI Institute, USA), Francesco Marzari (University of Padova, Italy), Motohide Tamura (National Astronomical Observatory, Japan), Mark Wyatt (University of Cambridge, UK), Hajime Yano (JAXA, Japan).

Star Formation in Different Environments
25 - 29 July 2016, Quy Nhon, Vietnam

This is the first conference on star formation in Vietnam. The last few years have changed drastically the landscape of star formation research, thanks to the successful operations of Herschel Space Observatory, ALMA, JCMT, PdBI, IRAM 30m, SMA...and the new development in numerical simulations and theory. We aim at to bringing together theorists and observers working on star formation, who would address the most recent advances in our knowledge of filament, core, cloud evolution and their interconnection. The conference will target to all aspects of star formation, including low-mass star formation, massive star formation, filamentary structure, giant molecular clouds, and galaxy-scale star formation. The workshop also aims at fostering close collaboration via smaller size focus groups.

The meeting consists of several invited talks (25min including 5min for Q&A), contributed talks (15min including 5min for Q&A), and posters. Selection of contributed talks will be done by the SOC by the end of May 2016. There will be time for focus group meetings and a half-day excursion. For young astronomers from developing countries, there will be also two days star formation bootcamp prior to the conference which cover fundamental knowledge of star formation.

SOC:

Philippe Andre (CEA), Henrik Beuther (MPIA), Ian Bonnell (St Andrew), Josep Girart (ICE), Alyssa Goodman (CfA), Doug Johnstone (NRC Herzberg), Paul Ho (EAO), Kee-Tae Kim (KASI), Kotaro Kohno (Univ. Tokyo), Mark Krumholz (ANU), Di Li (CAS), Hua Bai Li (CUHK), Sheng Yuan Liu (ASIAA), Chris Matzner (UofT), Karl Menten

(MPIfR), Thierry Montmerle (IAP), Frederique Motte (Grenoble), Fumitaka Nakamura (NAOJ, Chair), Toshikazu Onishi (Osaka Pref Univ.), Peter Schilke (Univ. Cologne), Ken'ichi Tatematsu (NAOJ), Koji Tomisaka (NAOJ)

LOC:

Quang Nguyen Luong (NAOJ), Jean Tran Thanh Van (rencontres du Vietnam), Le Minh Tan (Tay Nguyen univ.), Hoang Chi Thiem (CITA), Ha Trung Hieu (FTP univ.)

abstract registration deadline: 28 February 2016

website: http://sfde16.0x1115.org/

CLOUDY: Emission Lines in Astrophysics, From Gaseous Nebulae to Quasars

A Symposium to honor Gary Ferland

México City, 8-12 August 2016

The purpose of this symposium is to celebrate the scientific career of Gary Ferland. A substantial fraction of his research career has been devoted to the development of the code CLOUDY and its applications to the study of the interstellar medium. CLOUDY has been applied to a wide variety of astronomical environments including: photodissociation regions, molecular clouds, H II regions, planetary nebulae, novae and supernovae remnants, active galactic nuclei, and starburst galaxies.

During five days we will review those areas of astrophysics where the impact of CLOUDY has been important and we will try to glance into the future of interstellar medium research.

The proposed program is aimed at the most important issues related to the modeling of emission line interpretation under different astrophysical regimes. In particular the topics to cover would be:

Modeling Gaseous Nebulae
Atomic Data for Astrophysics
Active Galactic Nuclei Emission
Interstellar and circumstellar matter
Novae and Supernovae Remnants
H II Regions
Planetary Nebulae
Intergalactic Medium
Photodissociation Regions
Extending modelling capabilities

VENUE:
The venue will be Hotel Radisson Paraso with a special rate for participants of this conference.

HOW TO REGISTER:
We invite interested colleagues to pre-register through our webpage The pre-registration is open until 15 of January 2016. Notice that the number of participants is limited. The SOC will decide which type of presentation you will be able to give, and will communicate the result in early February 2016.

Scientific Organizing Committee:
Bozena Czerny, Andrew Fabian, William Henney, Frances Keenan, Ajit K. Kembhav, C. Robert O'Dell (co-chair), Manuel Peimbert (co-chair), Grazyna Stasinska, Thomas Troland, Tiangu Wang, and Martin Ward

Local Organizing Committee:
Rafael Costero, Gloria Delgado Inglada, Christophe Morisset, Antonio Peimbert, Miriam Pea, and Silvia Torres-Peimbert

CONTACT:
https://sites.google.com/a/astro.unam.mx/cloudy2016/
cloudy2016@astro.unam.mx

Summary of Upcoming Meetings

Protoplanetary Discussions
7 - 11 March 2016, Edinburgh, UK
http://www-star.st-and.ac.uk/ppdiscs

Molecular Gas in Galactic Environments
4 - 7 April 2016, Charlottesville, USA
https://science.nrao.edu/science/meetings/2016/molecular-gas-in-galactic-environments/

From Stars to Massive Stars
6 - 9 April 2016, Gainesville, Florida, USA
http://conference.astro.ufl.edu/STARSTOMASSIVE/

Water in the Universe - from Clouds to Oceans
12 - 15 April 2016, Noordwijk, The Netherlands
http://www.congrexprojects.com/2016-events/16A06/

Workshop on Young Solar Systems
18 - 22 April 2016, Barcelona, Spain
http://www.ice.csic.es/research/forum/Forum/2016a.html

From Star and Planet Formation to Early Life
25 - 28 April 2016 Vilnius, Lithuania
http://www.vilnius2016.eu

Resolving planet formation in the era of ALMA and extreme AO
16 - 20 May 2016, Santiago, Chile
http://www.eso.org/sci/meetings/2016/Planet-Formation2016.html

Diffuse Matter in the Galaxy, Magnetic Fields, and Star Formation - A Conference Honoring the Contributions of Richard Crutcher & Carl Heiles
22 - 25 May 2016, Madison, USA
http://www.astro.wisc.edu/ch16/

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

Cloudy Workshop
20 - 24 June 2016 Weihai, China
http://cloudy2016.csp.escience.cn/dct/page/1

EPoS 2016 The Early Phase of Star Formation - Progress after 10 years of EPoS
26 June - 1 July 2016, Ringberg Castle, Germany
http://www.mpia.de/homes/stein/EPoS/2016/2016.php

The role of feedback in the formation and evolution of star clusters
18 - 22 July 2016 Sexten, Italy
http://www.sexten-cfa.eu/en/conferences/2016/details/72-the-role-of-feedback-in-the-formation-and-evolution-

Binary Stars
24 - 30 July 2016, Cambridge, UK
http://www.ast.cam.ac.uk/meetings/2016/binary.stars.cambridge.2016

Star Formation in Different Environments
25 - 29 July 2016 Quy Nhon, Viet Nam
website to be announced

First Stars V
1 - 5 August 2016 Heidelberg, Germany
http://www.lsw.uni-heidelberg.de/FirstStarsV

CLOUDY: Emission Lines in Astrophysics
8 - 12 August 2016, Mexico City, Mexico
https://sites.google.com/a/astro.unam.mx/cloudy2016/

Cosmic Dust
15 - 19 August 2016, Sendaai, Japan
https://www.cps-jp.org/~dust/

Star Formation 2016
21-26 August 2016 Exeter, UK
http://www.astro.ex.ac.uk/sf2016

Interstellar shocks: models, observations & experiments
14-16 September 2016, Torun, Poland
http://shocks2016.faj.org.pl

Half a Decade of ALMA: Cosmic Dawns Transformed 20 - 23 September 2016 Indian Wells, USA
http://www.cvent.com/events/half-a-decade-of-alma-cosmic-dawns-transformed/event-summary-12c52aba23024057862

VIALACTEA2016: The Milky Way as a Star Formation Engine
26 - 30 September 2016, Rome, Italy
http://vialactea2016.iaps.inaf.it

The Local Truth: Galactic Star-formation and Feed-back in the SOFIA Era - Celebrating 50 years of airborne astronomy
16 - 20 October 2016, Pacific Grove, USA
http://www.sofia.usra.edu/Science/workshops/SOFIA_Conference_2016

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.