THE STAR FORMATION NEWSLETTER

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

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The Star Formation Newsletter

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

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List of Contents

Cover Picture

A molecular cloud ridge is flanking the western edge of the NGC 2068 HII region in the Orion B complex. A number of 850 μm sources are embedded in the ridge.

Composite image assembled by Robert Gendler from a deep Subaru SuprimeCam Hα image by Bo Reipurth, Chart 32 images by Johannes Schedler and other data.

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

Philip Myers

in conversation with Bo Reipurth

Q: *What was your PhD about, and what were the circumstances in that subject back in the early 1970s?*

A: My 1972 PhD from MIT was "Microwave Observations of Molecular Spectral Lines in Galactic Clouds," based on maps of lines of H I, OH, and H_2CO (formaldehyde) in nearby dark clouds. We knew about dark clouds and their structure from background star counts of the Palomar Sky Survey. Only a few interstellar molecules were known, but the high rate of new detections made this an exciting field. My advisor Alan Barrett had helped discover OH in absorption. Dark clouds were a new focus of interest because the 6-cm line of formaldehyde had recently been discovered in absorption against the cosmic microwave background. This presented an interesting problem of excitation. There was as of yet little discussion of star formation in dark clouds.

Q: *In the 1980s you wrote a series of six very influential papers on dense cores in dark clouds, discussing their column densities, turbulence, star formation, outflows, shapes.*

A: Dark clouds seemed to be good places to study star formation because they are close enough to resolve low-mass gas condensations, because we could see their extinction structure, and because many associated T Tauri stars were known. The problem was that in dark clouds, most available spectral lines were too weak to detect or map. Many observers were instead studying gas near more distant H II regions, where available lines were brighter.

As receivers became more sensitive at cm and mm wavelengths, it became practical to make small maps in dark clouds, in the 3-mm lines of ^{13}CO and $C^{18}O$ (carbon monoxide isotopologues) and the 1.3-cm lines of NH_3 (ammonia). For her thesis project, Priscilla Benson made a list of more than 100 spots of high extinction in nearby filamentary dark clouds, based on careful visual inspection of the Palomar prints. We got observing time to survey them in ammonia lines at the nearby MIT Haystack Observatory, at the 140-foot telescope of the NRAO in Green Bank, West Virginia, and at the 7-meter ATT telescope in Holmdel, New Jersey.

We found that most of these "dense core" positions were detectable in our survey lines, and we began to quantify their line properties and their map sizes. It was interesting that the ammonia line width was close to thermal in some cores, and that the corresponding core mass was close to 1 $M_\odot$, based on the map size and the density needed to excite the line. We estimated that the number of ammonia cores in the Taurus cloud complex was comparable to the number of T Tauri stars, supporting the idea that the cores could represent "initial conditions" for low-mass stars.

Q: *In the late 1980s the IRAS survey became available, and you studied the association of IRAS sources with dense cores. What did you learn?*

A: One day in 1984 Sue Terebey told me I should talk to Chas Beichman at the Jet Propulsion Laboratory because the IRAS survey was finding new far-infrared point sources in some of the dense cores we had catalogued. These results helped establish the idea that some stars are born in dense cores, and they motivated us to study these cores in greater detail. One of our findings was that dense core maps were usually elongated, and that their 3D structure was more likely to be prolate than oblate, especially when the cores are integral parts of much more elongated filamentary structures. These dense core observations also became useful for theoretical models of star-forming cores, particularly by Frank Shu and his colleagues.

Q: *You wrote with Alyssa Goodman two widely read papers in 1988 on magnetic support in molecular clouds in relation to ambipolar diffusion and virial equilibrium. What were the key results?*

A: These papers investigated the idea that in self-gravitating molecular clouds, the nonthermal kinetic energy seen in "turbulent" cloud line widths is due to magnetic field fluctuations, which are associated with gas motions at or near the Alfvén speed. These papers were stimulated by the prevalence of supersonic line widths and by the empirical line width-size relations described by Richard Larson in 1981. The first paper assembled a sample which doubled the number of data points analyzed by Larson. It found that the well-defined trend between nonthermal line width and cloud size could be matched if the magnetic field strength lay in the range 15-40 μG. The second paper presented field strengths derived from observations of the Zeeman effect in 14 clouds, in good agreement with the equipartition model from the first paper. The role of the magnetic field in molecular cloud physics is still widely discussed.

Q: *In 1992 you wrote with Gary Fuller a paper discussing* *dense cores with thermal and non-thermal motions.*

A: We explored the idea that the inside-out collapse model of a singular isothermal sphere could be extended to include the nonthermal motions observed in dense core line widths, if these nonthermal motions could be treated as a spherically symmetric source of isotropic pressure. We found that the effective sound speed of this "thermal-nonthermal (TNT)" model increases outward, so that the corresponding expansion wave speed also increases outward. The resulting star formation time shows relatively little variation from low-mass cores, which make low-mass stars, to massive cores, which make massive stars.

Q: *You and Edwin Ladd introduced in 1993 the concept of bolometric temperatures of YSOs in a paper that is still widely cited today. What was the central idea?*

A: We tried to quantify the "spectral evolutio" of protostellar spectral energy distributions (SEDs) from red for deeply embedded protostars to blue for T Tauri stars. The goal was to find a continuous variable which would have physical meaning and which would not require assigning boundaries between spectral "classes." We developed the "bolometric temperature (T_{bol})", the temperature of a blackbody having the same mean frequency as the observed spectrum. A diagram of log luminosity vs. log T_{bol} ("BLT diagram") is then an analog of the Hertzsprung-Russell diagram (HRD). A protostar starts its evolution at low luminosity, with T_{bol} close to the dense core temperature. It evolves toward a position on the H-R main sequence as its associated core and disk dissipate. Thus on the BLT diagram, two protostars with the same final mass will likely have the same initial position, and the same final position. However they may have different evolutionary tracks along the way, because their disks may present different axis directions to the line of sight.

Q: *Subsequently you turned your attention to spectral line profiles in contracting clouds. What did you learn?*

A: This work sought to identify and study signatures of contraction, in accreting and contracting clouds. We analyzed the blue-shifted spectral line asymmetry which arises when a line has optical depth of order unity, in a contracting cloud with line excitation temperature increasing inward. We found that many dense clouds and cores show such line asymmetry, depending on the choice of core and tracer line. The simplest case is in starless cores, where the line profile is not affected by protostellar outflows. The effective contraction speed is about half the sound speed. In some starless cores, the line asymmetry changes sign across the core map, suggesting a form of oscillation. Studies with Chang Won Lee and colleagues indicate that contracting motions dominate for cores with peak column density greater than $\sim 6\times 10^{21}$ cm^{-2}. It remains to be determined how much of the contraction can be ascribed to core growth and how much to core collapse.

Q: *More recently your interests have turned to the filamentary structure of star forming complexes, with the first paper appearing in 2009, and the most recent just a few months ago. What are the key insights here?*

A: Filamentary clouds have been interesting to me for a long time, since Priscilla Benson and I started making dense core lists in the 1970s. When Rob Gutermuth, Tom Megeath, and other *Spitzer* colleagues started producing images of nearby embedded clusters, I noticed that some of them have multiple filamentary extensions, and that some *Spitzer* images of clusters in infrared dark clouds have up to ten such extensions. The 2009 paper showed that "hub-filament structure" is a common pattern in the dense gas associated with nearby young stellar groups. This paper also presented a model for this structure, where a clump is compressed into a centrally concentrated version of the equilibrium Schmid-Burgk layer. In the recent 2017 paper, new axisymmetric models of filamentary clouds are presented, to estimate the star-forming potential of their dense gas from a simple Jeans-like analysis. Application to the filament harboring the Coronet cluster indicates that it has enough dense gas to form some eight new low-mass protostars, similar to the number already known.

Q: *You have also studied the protostar mass function in young clusters.*

A: This work started with the idea that our models of protostar mass in clusters have relied too much on collapse of a fixed mass of dense gas, and not enough on the competition between accretion and dispersal of dense gas. Seven papers from 2008 to 2014 followed this theme. A key question was, how does protostar accretion stop when the mass reservoir is not an isolated dense core, but instead is a core in an extended medium? Analytic models were made assuming that protostar accretion is equally likely to stop at any moment, due to outflows, ionization, and gravitational competition. In this picture the final mass of a star could be less than or greater than the initial core mass. It was found that the distribution of final star masses could match the initial mass function of field stars if the initial gas distribution has a steeply concentrated core component, surrounded by a shallower envelope component. This configuration could include chains of cores, and hub-filament systems. These ideas were applied to model protostar luminosity distributions, and to estimate the age and the birthrate of protostars in a young cluster, based on the ratio of protostars and older stars in the cluster. This criterion identified Serpens South as the youngest among 23 nearby clusters, and Carina as the youngest among seven nearby complexes. It remains an interesting problem why some regions seem to have a spatially concentrated burst of star formation.

Abstracts of recently accepted papers

An ALMA Survey of Protoplanetary Disks in the σ Orionis Cluster

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The σ Orionis cluster is important for studying protoplanetary disk evolution, as its intermediate age (∼3–5 Myr) is comparable to the median disk lifetime. We use ALMA to conduct a high-sensitivity survey of dust and gas in 92 protoplanetary disks around σ Orionis members with $M \gtrsim 0.1\ M_\odot$. Our observations cover the 1.33 mm continuum and several CO J=2–1 lines: out of 92 sources, we detect 37 in the mm continuum and six in ^{12}CO, three in ^{13}CO, and none in C^{18}O. Using the continuum emission to estimate dust mass, we find only 11 disks with $M_{\rm dust} \gtrsim 10\ M_\oplus$, indicating that after only a few Myr of evolution most disks lack sufficient dust to form giant planet cores. Stacking the individually undetected continuum sources limits their average dust mass to 5× lower than that of the faintest detected disk, supporting theoretical models that indicate rapid dissipation once disk clearing begins. Comparing the protoplanetary disk population in σ Orionis to those of other star-forming regions supports the steady decline in average dust mass and the steepening of the $M_{\rm dust}$–M relation with age; studying these evolutionary trends can inform the relative importance of different disk processes during key eras of planet formation. External photoevaporation from the central O9 star is influencing disk evolution throughout the region: dust masses clearly decline with decreasing separation from the photoionizing source, and the handful of CO detections exist at projected separations >1.5 pc. Collectively, our findings indicate that giant planet formation is inherently rare and/or well underway by a few Myr of age.

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On the Chemistry of the Young Massive Protostellar core NGC 2264 CMM3

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We present the first gas-grain astrochemical model of the NGC 2264 CMM3 protostellar core. The chemical evolution of the core is affected by changing its physical parameters such as the total density and the amount of gas-depletion onto grain surfaces as well as the cosmic ray ionisation rate, ζ. We estimated $\zeta_{\rm CMM3} = 1.6\times10^{-17}$ s^{-1}. This value is 1.3 times higher than the standard CR ionisation rate, $\zeta_{\rm ISM} = 1.3\times10^{-17}$ s^{-1}. Species response differently to changes into the core physical conditions, but they are more sensitive to changes in the depletion percentage and CR ionisation rate than to variations in the core density. Gas-phase models highlighted the importance of surface reactions as factories of large molecules and showed that for sulphur bearing species depletion is important to reproduce observations.
Comparing the results of the reference model with the most recent millimeter observations of the NGC 2264 CMM3 core showed that our model is capable of reproducing the observed abundances of most of the species during early stages ($\leq3\times10^4$ yrs) of their chemical evolution. Models with variations in the core density between (1–20) × 10^6

cm^{-3} are also in good agreement with observations during the early time interval $1 \times 10^4 < t$ (yr) $< 5 \times 10^4$. In addition, models with higher CR ionisation rates (5 −10) $\times \zeta_{\rm ISM}$ are often overestimating the fractional abundances of the species. However, models with $\zeta_{\rm CMM3} = 5\ \zeta_{\rm ISM}$ may best fit observations at times $\sim 2 \times 10^4$ yrs. Our results suggest that CMM3 is (1–5) $\times 10^4$ yrs old. Therefore, the core is chemically young and it may host a Class 0 object as suggested by previous studies.

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Fragmentation and disk formation in high-mass star formation: The ALMA view of G351.77-0.54 at $0.06''$ resolution

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Context: The fragmentation of high-mass gas clumps and the formation of the accompanying accretion disks lie at the heart of high-mass star formation research.
Aims: We resolve the small-scale structure around the high-mass hot core region G351.77-0.54 to investigate its disk and fragmentation properties.
Methods: Using the Atacama Large Millimeter Array at 690 GHz with baselines exceeding 1.5 km, we study the dense gas, dust and outflow emission at an unprecedented spatial resolution of $0.06''$ (130 AU @2.2 kpc).
Results: Within the inner few 1000 AU, G351.77 fragments into at least four cores (brightness temperatures between 58 and 197 K). The central structure around the main submm source #1 with a diameter of $\sim 0.5''$ does not show additional fragmentation. While the CO(6-5) line wing emission shows an outflow lobe in the north-western direction emanating from source #1, the dense gas tracer CH_3CN shows a velocity gradient perpendicular to the outflow that is indicative of rotational motions. Absorption profile measurements against the submm source #2 indicate infall rates on the order of 10^{-4} to $10^{-3}\,M_\odot\,yr^{-1}$ which can be considered as an upper limit of the mean accretion rates. The position-velocity diagrams are consistent with a central rotating disk-like structure embedded in an infalling envelope, but they may also be influenced by the outflow. Using the $CH_3CN(37_k - 36_k)$ $k-$ladder with excitation temperatures up to 1300 K, we derive a gas temperature map of source #1 exhibiting temperatures often in excess of 1000 K. Brightness temperatures of the submm continuum never exceed 200 K. This discrepancy between gas temperatures and submm dust brightness temperatures (in the optically thick limit) indicates that the dust may trace the disk mid-plane whereas the gas could be tracing a hotter gaseous disk surface layer. In addition, we conduct a pixel-by-pixel Toomre gravitational stability analysis of the central rotating structure. The derived high Q values throughout the structure confirm that this central region appears stable against gravitational instability.
Conclusions: Resolving for the first time a high-mass hot core at $0.06''$ resolution at submm wavelengths in the dense gas and dust emission allowed us to trace the fragmenting core and the gravitationally stable inner rotating disk-like structure. A temperature analysis reveals hot gas and comparably colder dust that may be attributed to different disk locations traced by dust emission and gas lines. The kinematics of the central structure #1 reveal contributions from a rotating disk, an infalling envelope and potentially also an outflow, whereas the spectral profile toward source #2 can be attributed to infall.

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http://www.mpia-hd.mpg.de/homes/beuther/papers.html

Cosmic-ray induced destruction of CO in star-forming galaxies

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We explore the effects of the expected higher cosmic ray (CR) ionization rates $\zeta_{\rm CR}$ on the abundances of carbon monoxide (CO), atomic carbon (C), and ionized carbon (C^+) in the H_2 clouds of star-forming galaxies. The study of Bisbas et al. (2015) is expanded by: a) using realistic inhomogeneous Giant Molecular Cloud (GMC) structures, b) a detailed chemical analysis behind the CR-induced destruction of CO, and c) exploring the thermal state of CR-irradiated molecular gas. CRs permeating the interstellar medium with $\zeta_{\rm CR}\gtrsim 10\times$(Galactic) are found to significantly reduce the [CO]/[H_2] abundance ratios throughout the mass of a GMC. CO rotational line imaging will then show much clumpier structures than the actual ones. For $\zeta_{\rm CR}\gtrsim 100\times$(Galactic) this bias becomes severe, limiting the utility of CO lines for recovering structural and dynamical characteristics of H_2-rich galaxies throughout the Universe, *including many of the so-called Main Sequence (MS) galaxies* where the bulk of cosmic star formation occurs. Both C^+ and C abundances increase with rising $\zeta_{\rm CR}$, with C remaining the most abundant of the two throughout H_2 clouds, when $\zeta_{\rm CR}\sim(1-100)\times$(Galactic). C^+ starts to dominate for $\zeta_{\rm CR}\gtrsim 10^3\times$(Galactic). The thermal state of the gas in the inner and denser regions of GMCs is invariant with $T_{\rm gas}\sim 10\,{\rm K}$ for $\zeta_{\rm CR}\sim(1-10)\times$(Galactic). For $\zeta_{\rm CR}\sim 10^3\times$(Galactic) this is no longer the case and $T_{\rm gas}\sim 30-50\,{\rm K}$ are reached. Finally we identify OH as the key species whose $T_{\rm gas}-$sensitive abundance could mitigate the destruction of CO at high temperatures.

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Accurate sub-millimetre rest-frequencies for $HOCO^+$ and $DOCO^+$ ions

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$HOCO^+$ is a polar molecule that represents a useful proxy for its parent molecule CO_2, which is not directly observable in the cold interstellar medium. This cation has been detected towards several lines of sight, including massive star forming regions, protostars, and cold cores. Despite the obvious astrochemical relevance, protonated CO_2 and its deuterated variant, $DOCO^+$, still lack an accurate spectroscopic characterisation. The aim of this work is to extend the study of the ground-state pure rotational spectra of $HOCO^+$ and $DOCO^+$ well into the sub-millimetre region. Ground-state transitions have been recorded in the laboratory using a frequency-modulation absorption spectrometer equipped with a free-space glow-discharge cell. The ions were produced in a low-density, magnetically-confined plasma generated in a suitable gas mixture. The ground-state spectra of $HOCO^+$ and $DOCO^+$ have been investigated in the 213–967 GHz frequency range, with the detection of 94 new rotational transitions. Additionally, 46 line positions taken from the literature have been accurately remeasured. The newly-measured lines have significantly enlarged the available data sets for $HOCO^+$ and $DOCO^+$, thus enabling the determination of highly accurate rotational and centrifugal distortion parameters. Our analysis showed that all $HOCO^+$ lines with $K_a\geq 3$ are perturbed by a ro-vibrational interaction that couples the ground state with the $v_5 = 1$ vibrationally-excited state. This resonance has been explicitly treated in the analysis in order to obtain molecular constants with clear physical meaning. The improved sets of spectroscopic parameters provide enhanced lists of very accurate, sub-millimetre rest-frequencies of $HOCO^+$ and $DOCO^+$ for astrophysical applications. These new data challenges a recent tentative identification of $DOCO^+$ toward a pre-stellar core.

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Exploring molecular complexity with ALMA (EMoCA): Detection of three new hot cores in Sagittarius B2(N)

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The Sagittarius B2 molecular cloud contains several sites forming high-mass stars. Sgr B2(N) is one of its main centers of activity. It hosts several compact and ultra-compact HII regions, as well as two known hot molecular cores (Sgr B2(N1) and Sgr B2(N2)) in the early stage of the high-mass star formation process, where complex organic molecules (COMs) are detected in the gas phase. Our goal is to use the high sensitivity of the Atacama Large Millimeter/submillimeter Array (ALMA) to characterize the hot core population in Sgr B2(N) and thereby shed a new light on the star formation process in this star-forming region. We use a complete 3 mm spectral line survey conducted with ALMA to search for faint hot cores in the Sgr B2(N) region. The chemical composition of the detected sources and the column densities are derived by modelling the whole spectra under the assumption of local thermodynamic equilibrium. Population diagrams are constructed to fit rotational temperatures. Integrated intensity maps are produced to derive the peak position and fit the size of each molecules emission distribution. The kinematic structure of the hot cores is investigated by analyzing the line wing emission of typical outflow tracers. The H_2 column densities are computed from ALMA and SMA continuum emission maps. We report the discovery of three new hot cores in Sgr B2(N) that we call Sgr B2(N3), Sgr B2(N4), and Sgr B2(N5). The three sources are associated with class II methanol masers, well known tracers of high-mass star formation, and Sgr B2(N5) also with a UCHII region. Their H_2 column densities are found to be $\sim$ 16 up to 36 times lower than the one of the main hot core Sgr B2(N1). The spectra of these new hot cores have spectral line densities of 11 up to 31 emission lines per GHz above the 7σ level, assigned to 22–25 molecules plus 13–20 less abundant isotopologs. We derive rotational temperatures around 140–180 K for the three new hot cores and mean source sizes of $0.4''$ for Sgr B2(N3) and $1.0''$ for Sgr B2(N4) and Sgr B2(N5). The chemical composition of Sgr B2(N3), Sgr B2(N4), and Sgr B2(N5) is very similar, but it differs from that of Sgr B2(N2). Finally, Sgr B2(N3) and Sgr B2(N5) show high velocity wing emission in typical outflow tracers, with a bipolar morphology in their integrated intensity maps suggesting the presence of an outflow, like in Sgr B2(N1). No sign of an outflow is found around Sgr B2(N2) and Sgr B2(N4). We derive statistical lifetimes of $4{\times}10^4$ yr for the class II methanol maser phase and $6{\times}10^4$ yr for the hot core phase in Sgr B2(N). The associations of the hot cores with class II methanol masers, outflows, and/or UCHII regions tentatively suggest the following age sequence: Sgr B2(N4), Sgr B2(N3), SgrB2(N5), Sgr B2(N1). The status of Sgr B2(N2) is unclear. It may contain two distinct sources, a UCHII region and a very young hot core.

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Planetesimal formation by the streaming instability in a photoevaporating disk

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Recent years have seen growing interest in the streaming instability as a candidate mechanism to produce planetesimals. However, these investigations have been limited to small-scale simulations. We now present the results of a global protoplanetary disk evolution model that incorporates planetesimal formation by the streaming instability, along with viscous accretion, photoevaporation by EUV, FUV, and X-ray photons, dust evolution, the water ice line, and stratified turbulence. Our simulations produce massive (60–130 $M_{\oplus}$) planetesimal belts beyond 100 au and up to $\sim$20 $M_{\oplus}$ of planetesimals in the middle regions (3–100 au). Our most comprehensive model forms 8 $M_{\oplus}$ of planetesimals inside 3 au, where they can give rise to terrestrial planets. The planetesimal mass formed in the inner disk depends critically on the timing of the formation of an inner cavity in the disk by high-energy photons. Our results show that the combination of photoevaporation and the streaming instability are efficient at converting the solid component of protoplanetary disks into planetesimals. Our model, however, does not form enough early planetesimals in the inner and middle regions of the disk to give rise to giant planets and super-Earths with gaseous envelopes. Additional processes such as particle pileups and mass loss driven by MHD winds may be needed to drive the formation of early planetesimal generations in the planet forming regions of protoplanetary disks.

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Dynamical timescale of precollapse evolution inferred from chemical distribution in the Taurus Molecular Cloud-1 (TMC-1) filament

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We present observations and analysis of the low-mass star-forming region, Taurus Molecular Cloud-1 (TMC-1). CS (J=2–1)/N_2H^+ (J=1–0) and $C^{17}O$ (J=2–1)/$C^{18}O$ (J=2–1) were observed with FCRAO (Five College Radio Astronomy Observatory) and SRAO (Seoul Radio Astronomy Observatory), respectively. In addition, *Spitzer* infrared data and 1.2 mm continuum data observed with MAMBO (Max-Planck Millimetre Bolometer) are used. We also perform chemical modeling to investigate the relative molecular distributions of the TMC-1 filament. Based on *Spitzer* observations, there is no young stellar object along the TMC-1 filament, while five Class II and one Class I young stellar objects are identified outside the filament. The comparison between column densities calculated from dust continuum and $C^{17}O$ 2–1 line emission shows that CO is depleted much more significantly in the ammonia peak than in the cyanopolyyne peak, while the column densities calculated from the dust continuum are similar at the two peaks. N_2H^+ is not depleted much in either peak. According to our chemical calculation, the differential chemical distribution in the two peaks can be explained by different timescales required to reach the same density, i.e., by different dynamical processes.

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Filamentary fragmentation in a turbulent medium

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We present the results of smoothed particle hydrodynamic simulations investigating the evolution and fragmentation of filaments that are accreting from a turbulent medium. We show that the presence of turbulence, and the resulting inhomogeneities in the accretion flow, play a significant role in the fragmentation process. Filaments which experience a weakly turbulent accretion flow fragment in a two-tier hierarchical fashion, similar to the fragmentation pattern seen in the Orion Integral Shaped Filament. Increasing the energy in the turbulent velocity field results in more sub-structure within the filaments, and one sees a shift from gravity-dominated fragmentation to turbulence-dominated fragmentation. The sub-structure formed in the filaments is elongated and roughly parallel to the longitudinal axis of the filament, similar to the fibres seen in observations of Taurus, and suggests that the *fray and fragment* scenario is a possible mechanism for the production of fibres. We show that the formation of these fibre-like structures is linked to the vorticity of the velocity field inside the filament and the filament's accretion from an inhomogeneous medium. Moreover, we find that accretion is able to drive and sustain roughly sonic levels of turbulence inside the filaments, but is not able to prevent radial collapse once the filaments become supercritical. However, the supercritical filaments which contain fibre-like structures do not collapse radially, suggesting that fibrous filaments may not necessarily become radially unstable once they reach the critical line-density.

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Formulas for Radial Transport in Protoplanetary Disks

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Quantification of the radial transport of gaseous species and solid particles is important to many applications in protoplanetary disk evolution. An especially important example is determining the location of the water snow lines in a disk, which requires computing the rates of outward radial diffusion of water vapor and the inward radial drift of icy particles; however, the application is generalized to evaporation fronts of all volatiles. We review the relevant formulas using a uniform formalism. This uniform treatment is necessary because the literature currently contains at least six mutually exclusive treatments of radial diffusion of gas, only one of which is correct. We derive the radial diffusion equations from first principles, using Fick's law. For completeness, we also present the equations for radial transport of particles. These equations may be applied to studies of diffusion of gases and particles in protoplanetary and other accretion disks.

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Effects of Pre-ionisation in Radiative Shocks II: Application to the Herbig-Haro Objects

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In an earlier paper we treated the pre-ionisation problem in shocks over the velocity range $20 < v_{\rm s} < 1000$ km s^{-1} in a fully self-consistent manner. Here we investigate in detail the effect of the upstream UV photon field generated in the radiative zone of shocks in the range in which hydrogen is only partly ionised ($20 < v_{\rm s} < 150$ km s^{-1}). We show that, as a result of super-heating in the non-equilibrium pre-shock plasma, both the magnetic parameter and the Mach number of the shock is strongly affected by the pre-ionisation state of the gas which controls to a large extent the radiative spectrum of the shock. We use these models to provide specific line diagnostics for Herbig-Haro objects which allow us to solve for both the pre-shock density and shock velocity, and present detailed models of the HH34 jet which allows us to derive the shock conditions, mass-loss rate, momentum flux and chemical abundances in the jet. We show that the refractory elements, Mg, Ca, Fe and Ni are enhanced by 0.22 dex over the solar values, which provides interesting clues about the jet launching mechanism in pre-main sequence evolution.

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A search for passive protoplanetary disks in the Taurus-Auriga star-forming region

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We conducted a 12-month monitoring campaign of 33 T Tauri stars (TTS) in Taurus. Our goal was to monitor objects that possess a disk but have a weak Hα line, a common accretion tracer for young stars, to determine whether they host a passive circumstellar disk. We used medium-resolution optical spectroscopy to assess the objects' accretion status and to measure the Hα line. We found no convincing example of passive disks; only transition disk and debris disk systems in our sample are non-accreting. Among accretors, we find no example of flickering accretion, leading to an upper limit of 2.2% on the duty cycle of accretion gaps assuming that all accreting TTS experience such events. Combining literature results with our observations, we find that the reliability of traditional Hα-based criteria to test for accretion is high but imperfect, particularly for low-mass TTS. We find a significant correlation between stellar mass and the full width at 10 per cent of the peak ($W_{10\%}$) of the Hα line that does not seem to be related to variations in free-fall velocity. Finally, our data reveal a positive correlation between the Hα equivalent width and its $W_{10\%}$, indicative of a systematic modulation in the line profile whereby the high-velocity wings of the line are proportionally more enhanced than its core when the line luminosity increases. We argue that this supports the hypothesis that the mass accretion rate on the central star is correlated with the Hα $W_{10\%}$ through a common physical mechanism.

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NGC 1980 is not a foreground population of Orion: Spectroscopic survey of young stars with low extinction in Orion A

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We perform a spectroscopic survey of the foreground population in Orion A with MMT/Hectospec. We use these data, along with archival spectroscopic data and photometric data, to derive spectral types, extinction values, and masses for 691 stars. Using the Spitzer Space Telescope data, we characterize the disk properties of these sources. We identify 37 new transition disk (TD) objects, one globally depleted disk candidate, and 7 probable young debris disks. We discover an object with a mass less than 0.018–0.030 $M_{\odot}$, which harbors a flaring disk. Using the Hα emission line, we characterize the accretion activity of the sources with disks, and confirm that fraction of accreting TDs is lower than that of optically thick disks (46±7% versus 73±9%, respectively). Using kinematic data from the Sloan Digital

Sky Survey and APOGEE INfrared Spectroscopy of Young Nebulous Clusters program (IN-SYNC), we confirm that the foreground population shows similar kinematics to their local molecular clouds and other young stars in the same regions. Using the isochronal ages, we find that the foreground population has a median age around 1–2 Myr, which is similar to the one of other young stars in Orion A. Therefore, our results argue against the presence of a large and old foreground cluster in front of Orion A.

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Protostellar accretion traced with chemistry. High resolution $C^{18}O$ and continuum observations towards deeply embedded protostars in Perseus

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Context. Understanding how accretion proceeds is a key question of star formation, with important implications for both the physical and chemical evolution of young stellar objects. In particular, very little is known about the accretion variability in the earliest stages of star formation.

Aims. To characterise protostellar accretion histories towards individual sources by utilising sublimation and freeze-out chemistry of CO.

Methods. A sample of 24 embedded protostars are observed with the Submillimeter Array (SMA) in context of the large program "Mass Assembly of Stellar Systems and their Evolution with the SMA" (MASSES). The size of the $C^{18}O$ emitting region, where CO has sublimated into the gas-phase, is measured towards each source and compared to the expected size of the region given the current luminosity. The SMA observations also include 1.3 mm continuum data, which are used to investigate whether a link can be established between accretion bursts and massive circumstellar disks.

Results. Depending on the adopted sublimation temperature of the CO ice, between 20% and 50% of the sources in the sample show extended $C^{18}O$ emission indicating that the gas was warm enough in the past that CO sublimated and is currently in the process of refreezing; something which we attribute to a recent accretion burst. Given the fraction of sources with extended $C^{18}O$ emission, we estimate an average interval between bursts of 20000 yr–50000 yr, which is consistent with previous estimates. No clear link can be established between the presence of circumstellar disks and accretion bursts, however the three closest known binaries in the sample (projected separations <20 AU) all show evidence of a past accretion burst, indicating that close binary interactions may also play a role in inducing accretion variability.

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Orbital Evolution of Moons in Weakly Accreting Circumplanetary Disks

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We investigate the formation of hot and massive circumplanetary disks (CPDs) and the orbital evolution of satellites formed in these disks. Because of the comparatively small size-scale of the sub-disk, quick magnetic diffusion prevents the magnetorotational instability (MRI) from being well-developed at ionization levels that would allow MRI in the parent protoplanetary disk. In the absence of significant angular momentum transport, continuous mass supply from the parental protoplanetary disk leads to the formation of a massive CPD. We have developed an evolutionary model for this scenario and have estimated the orbital evolution of satellites within the disk. We find, in a certain temperature range, that inward migration of a satellite can be stopped by a change in the structure due to the opacity transitions. Moreover, by capturing second and third migrating satellites in mean motion resonances, a compact system in Laplace resonance can be formed in our disk models.

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A search for water maser emission from brown dwarfs and low-luminosity young stellar objects

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We present a survey for water maser emission toward a sample of 44 low-luminosity young objects, comprising (proto-)brown dwarfs, first hydrostatic cores (FHCs), and other young stellar objects (YSOs) with bolometric luminosities lower than 0.4 $L_\odot$. Water maser emission is a good tracer of energetic processes, such as mass-loss and/or accretion, and is a useful tool to study this processes with very high angular resolution. This type of emission has been confirmed in objects with $L_{bol} \geq 1$ $L_\odot$. Objects with lower luminosities also undergo mass-loss and accretion, and thus, are prospective sites of maser emission. Our sensitive single-dish observations provided a single detection when pointing toward the FHC L1448 IRS 2E. However, follow-up interferometric observations showed water maser emission associated with the nearby YSO L1448 IRS 2 (a Class 0 protostar of $L_{bol} \simeq 3.6-5.3$ $L_\odot$), and did not find any emission toward L1448 IRS 2E. The upper limits for water maser emission determined by our observations are one order of magnitude lower than expected from the correlation between water maser luminosities and bolometric luminosities found for YSOs. This suggests that this correlation does not hold at the lower end of the (sub)stellar mass spectrum. Possible reasons are that the slope of this correlation is steeper at $L_{bol} \leq 1$ $L_\odot$, or that there is an absolute luminosity threshold below which water maser emission cannot be produced. Alternatively, if the correlation still stands at low luminosity, the detection rates of masers would be significantly lower than the values obtained in higher-luminosity Class 0 protostars.

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Gravitational collapse of the OMC-1 region

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We have investigated the global dynamical state of the Integral Shaped Filament in the Orion A cloud using new N_2H^+ (1-0) large-scale, IRAM30m observations. Our analysis of its internal gas dynamics reveals the presence of accelerated motions towards the Orion Nebula Cluster, showing a characteristic blue-shifted profile centred at the position of the OMC-1 South region. The properties of these observed gas motions (profile, extension, and magnitude) are consistent with the expected accelerations for the gravitational collapse of the OMC-1 region and explain both the physical and kinematic structure of this cloud.

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Fibers in the NGC1333 proto-cluster

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Are the initial conditions for clustered star formation the same as for non-clustered star formation? To investigate the initial gas properties in young proto-clusters we carried out a comprehensive and high-sensitivity study of the internal structure, density, temperature, and kinematics of the dense gas content of the NGC1333 region in Perseus, one of the nearest and best studied embedded clusters. The analysis of the gas velocities in the Position-Position-Velocity space reveals an intricate underlying gas organization both in space and velocity. We identified a total of 14 velocity-coherent, (tran-)sonic structures within NGC1333, with similar physical and kinematic properties than those quiescent, star-forming (aka fertile) fibers previously identified in low-mass star-forming clouds. These fibers are arranged in a complex spatial network, build-up the observed total column density, and contain the dense cores and protostars in this cloud. Our results demonstrate that the presence of fibers is not restricted to low-mass clouds but can be extended to regions of increasing mass and complexity. We propose that the observational dichotomy between clustered and non-clustered star-forming regions might be naturally explained by the distinct spatial density of fertile fibers in these environments.

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Massive star formation by accretion II. Rotation: how to circumvent the angular momentum barrier?

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Rotation plays a key role in the star-formation process, from pre-stellar cores to pre-main-sequence (PMS) objects. Understanding the formation of massive stars requires taking into account the accretion of angular momentum during their PMS phase. We study the PMS evolution of objects destined to become massive stars by accretion, focusing on the links between the physical conditions of the environment and the rotational properties of young stars. In particular, we look at the physical conditions that allow the production of massive stars by accretion. We present PMS models computed with a new version of the Geneva Stellar Evolution code self-consistently including accretion and rotation according to various accretion scenarios for mass and angular momentum. We describe the internal distribution of angular momentum in PMS stars accreting at high rates and we show how the various physical conditions impact their internal structures, evolutionary tracks, and rotation velocities during the PMS and the early main sequence.

We find that the smooth angular momentum accretion considered in previous studies leads to an angular momentum barrier and does not allow the formation of massive stars by accretion. A braking mechanism is needed in order to circumvent this angular momentum barrier. This mechanism has to be efficient enough to remove more than 2/3 of the angular momentum from the inner accretion disc. Due to the weak efficiency of angular momentum transport by shear instability and meridional circulation during the accretion phase, the internal rotation profiles of accreting stars reflect essentially the angular momentum accretion history. As a consequence, careful choice of the angular momentum accretion history allows circumvention of any limitation in mass and velocity, and production of stars of any mass and velocity compatible with structure equations.

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Radio observations of globulettes in the Carina nebula

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The Carina nebula hosts a large number of globulettes. The majority are of planetary mass, but there are also those with masses of several tens up to a few hundred Jupiter masses. We carried out radio observations of molecular line emission in ^{12}CO and ^{13}CO (2–1) and (3–2) of 12 larger objects in addition of positions in adjacent shell structures using APEX. All selected objects were detected with radial velocities shifted relative to the emission from related shell structures and background molecular clouds. Globulettes along the western part of an extended dust shell show a small spread in velocity with small velocity shifts relative to the shell. This system of globulettes and shell structures in the foreground of the bright nebulosity surrounding the cluster Trumpler 14 is expanding with a few km s^{-1} relative to the cluster. The Carina globulettes are compact and denser than objects of similar mass studied previously in the Rosette nebula. Some globulettes in Tr 14 are located far from any shell structures. These objects move at a similar speed as the globulettes along the shell. The distribution and velocities of the globulettes studied suggest that they have originated from eroding shells and elephant trunks.

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First evidence of external disc photoevaporation in a low mass star forming region: the case of IM Lup

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We model the radiatively driven flow from IM Lup — a large protoplanetary disc expected to be irradiated by only a weak external radiation field (at least 10^4 times lower than the UV field irradiating the Orion Nebula Cluster proplyds). We find that material at large radii (>400AU) in this disc is sufficiently weakly gravitationally bound that significant mass loss can be induced. Given the estimated values of the disc mass and accretion rate, the viscous timescale is long (∼10 Myr) so the main evolutionary behaviour for the first Myr of the disc's lifetime is truncation of the disc by photoevaporation, with only modest changes effected by viscosity. We also produce approximate synthetic observations of our models, finding substantial emission from the flow which can explain the CO halo observed about IM Lup out to ≥1000 AU. Solutions that are consistent with the extent of the observed CO emission generally imply that IM Lup is still in the process of having its disc outer radius truncated. We conclude that IM Lup is subject to substantial external photoevaporation, which raises the more general possibility that external irradiation of the largest discs can be of significant importance even in low mass star forming regions.

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Detection of submillimeter-wave [C I] emission in gaseous debris disks of 49 Ceti and β Pictoris

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We have detected [C I] $^3P_1$–$^3P_0$ emissions in the gaseous debris disks of 49 Ceti and β Pictoris with the 10 m telescope of the Atacama Submillimeter Telescope Experiment, which is the first detection of such emissions. The line profiles of [C I] are found to resemble those of CO(J=3–2) observed with the same telescope and the Atacama Large Millimeter/submillimeter Array. This result suggests that atomic carbon (C) coexists with CO in the debris disks, and is likely formed by the photodissociation of CO. Assuming an optically thin [C I] emission with the excitation temperature ranging from 30 to 100 K, the column density of C is evaluated to be $(2.2\pm0.2)\times10^{17}$ and $(2.5\pm0.7)\times10^{16}$ cm^{-2} for 49 Ceti and β Pictoris, respectively. The C/CO column density ratio is thus derived to be 54±19 and 69±42 for 49 Ceti and β Pictoris, respectively. These ratios are higher than those of molecular clouds and diffuse clouds by an order of magnitude. The unusually high ratios of C to CO are likely attributed to a lack of H_2 molecules needed to reproduce CO molecules efficiently from C. This result implies a small number of H_2 molecules in the gas disk; i.e., there is an appreciable contribution of secondary gas from dust grains.

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Gravito-turbulence in irradiated protoplanetary discs

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Using radiation hydrodynamics simulations in a local stratified shearing box with realistic equations of state and opacities, we explored the outcome of self-gravity at 50 AU in a protoplanetary disc irradiated by the central star. We found that gravito-turbulence is sustained for a finite range of the surface density, from ∼80 to ∼250 g cm^{-2}. The disk is laminar below the range while fragments above it. In the range of gravito-turbulence, the Toomre parameter decreases monotonically from ∼1 to ∼0.7 as the surface density increases while an effective cooling time is almost constant at ∼4 in terms of the inverse of the orbital frequency. The turbulent motions are supersonic at all heights, which dissipates through both shock waves and compressional heating. The compressional motions, occurring near the midplane, create upward flows, which not only contribute to supporting the disc but also to transporting the dissipated energy to the disc surfaces. The irradiation does not affect much the gravito-turbulence near the midplane unless the grazing angle is larger than 0.32. We also show that a simple cooling function with a constant cooling time does not approximate the realistic cooling.

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On the effective turbulence driving mode of molecular clouds formed in disc galaxies

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We determine the physical properties and turbulence driving mode of molecular clouds formed in numerical simulations of a Milky Way-type disc galaxy with parsec-scale resolution. The clouds form through gravitational fragmentation of the gas, leading to average values for mass, radii and velocity dispersion in good agreement with observations of Milky Way clouds. The driving parameter (b) for the turbulence within each cloud is characterised by the ratio of the density contrast (σ_{ρ/ρ_0}) to the average Mach number ($\mathcal{M}$) within the cloud, $b = \sigma_{\rho/\rho_0}/\mathcal{M}$. As shown in previous works, $b \sim 1/3$ indicates solenoidal (divergence-free) driving and $b \sim 1$ indicates compressive (curl-free) driving. We find that the average b value of all the clouds formed in the simulations has a lower limit of $b > 0.2$. Importantly, we find that b has a broad distribution, covering values from purely solenoidal to purely compressive driving. Tracking the evolution of individual clouds reveals that the b value for each cloud does not vary significantly over their lifetime. Finally, we perform a resolution study with minimum cell sizes of 8, 4, 2 and 1 pc and find that the average b value increases with increasing resolution. Therefore, we conclude that our measured b values are strictly lower limits and that a resolution better than 1 pc is required for convergence. However, regardless of the resolution, we find that b varies by factors of a few in all cases, which means that the effective driving mode alters significantly from cloud to cloud.

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Variations on Debris Disks IV. An Improved Analytical Model for Collisional Cascades

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We derive a new analytical model for the evolution of a collisional cascade in a thin annulus around a single central star. In this model, r_{max} the size of the largest object changes with time, $r_{max} \propto t^{-\gamma}$, with $\gamma \approx$ 0.1–0.2. Compared to standard models where r_{max} is constant in time, this evolution results in a more rapid decline of M_d the total mass of solids in the annulus and L_d the luminosity of small particles in the annulus: $M_d \propto t^{-(\gamma+1)}$ and $L_d \propto t^{-(\gamma/2+1)}$. We demonstrate that the analytical model provides an excellent match to a comprehensive suite of numerical coagulation simulations for annuli at 1 AU and at 25 AU. If the evolution of real debris disks follows the predictions of the analytical or numerical models, the observed luminosities for evolved stars require up to a factor of two more mass than predicted by previous analytical models.

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The star formation environment of the FU Ori type star V582 Aur

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We have studied the environment of the FU Ori type star V582 Aur. Our aim is to explore the star-forming region associated with this young eruptive star. Using slitless spectroscopy we searched for Hα emission stars within a field of 11.5 $arcmin \times 11.5$ $arcmin$, centred on V582 Aur. Based on UKIDSS and Spitzer Space Telescope data we further selected infrared-excess young stellar object candidates. In all, we identified 68 candidate low-mass young stars, 16 of which exhibited Hα emission in the slitless spectroscopic images. The colour–magnitude diagram of the selected objects, based on IPHAS data, suggests that they are low-mass pre-main-sequence stars associated with the Aur OB 1 association, located at a distance of 1.3 kpc from the Sun. The bright-rimmed globules in the local environment of V582 Aur probably belong to the dark cloud LDN 1516. Our results suggest that star formation in these globules might have been triggered by the radiation field of a few hot members of Aur OB 1. The bolometric luminosity of V582 Aur, based on archival photometric data and on the adopted distance, is 150–320 $L_\odot$.

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H_2, CO, and Dust Absorption through Cold Molecular Clouds

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The abundance of H_2 in molecular clouds, relative to the commonly used tracer CO, has only been measured toward a few embedded stars, which may be surrounded by atypical gas. We present observations of near-infrared absorption by H_2, CO, and dust toward stars behind molecular clouds, providing a representative sample of these molecules in cold molecular gas, primarily in the Taurus Molecular Cloud. We find $N_{\mathrm{H_2}}/A_\mathrm{V} \sim 1.0 \times 10^{21}$ cm^{-2}, $N_\mathrm{CO}/A_\mathrm{V} \sim 1.5 \times 10^{17}$ cm^{-2} (1.8×10^{17} including solid CO), and $N_{\mathrm{H_2}}/N_\mathrm{CO} \sim 6000$. The measured $N_{\mathrm{H_2}}/N_\mathrm{CO}$ ratio is consistent with that toward embedded stars in various molecular clouds, but both are less than that derived from mm-wave observations of CO and star counts. The difference apparently results from the higher directly measured $N_\mathrm{CO}/A_\mathrm{V}$ ratio.

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Distribution of water in the G327.3−0.6 massive star-forming region

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We aim at characterizing the large-scale distribution of H_2O in G327.3−0.6, a massive star-forming region made of individual objects in different evolutionary phases. We investigate variations of H_2O abundance as function of evolution. We present Herschel continuum maps at 89 and 179 μm of the whole region and an APEX map at 350 μm of the IRDC. New spectral HIFI maps toward the IRDC region covering low-energy H_2O lines at 987 and 1113 GHz are also presented and combined with HIFI pointed observations of the G327 hot core. We infer the physical properties of the gas through optical depth analysis and radiative transfer modeling. The continuum emission at 89 and 179 μm follows the thermal continuum emission at longer wavelengths, with a peak at the position of the hot core, a secondary peak in the HII region, and an arch-like layer of hot gas west of the HII region. The same morphology is observed in the 1113 GHz line, in absorption toward all dust condensations. Optical depths of ∼80 and 15 are estimated and correspond to column densities of 10^{15} and 2×10^{14} cm^{-2}, for the hot core and IRDC position. These values indicate an H_2O to H_2 ratio of 3×10^{-8} toward the hot core; the abundance of H_2O does not change along the IRDC with values of some 10^{-8}. Infall (over ∼20″) is detected toward the hot core position with a rate of (1–1.3) $\times 10^{-2}$ $M_\odot$ yr^{-1}, high enough to overcome the radiation pressure due to the stellar luminosity. The source structure of the hot core region is complex, with a cold outer gas envelope in expansion, situated between the outflow and the observer, extending over 0.32 pc. The outflow is seen face-on and centered away from the hot core. The distribution of H_2O along the IRDC is roughly constant with an abundance peak in the more evolved object. These water abundances are in agreement with previous studies in other massive objects and chemical models.

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Does turbulence determine the initial mass function?

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We test the hypothesis that the initial mass function (IMF) is determined by the density probability distribution function (PDF) produced by supersonic turbulence. We compare 14 simulations of star cluster formation in 50 solar mass molecular cloud cores where the initial turbulence contains either purely solenoidal or purely compressive modes, in each case resolving fragmentation to the opacity limit to determine the resultant IMF. We find statistically indistinguishable IMFs between the two sets of calculations, despite a factor of two difference in the star formation rate and in the standard deviation of $\log(\rho)$. This suggests that the density PDF, while determining the star formation rate, is not the primary driver of the IMF.

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The Molecular Gas Environment in the 20 km s^{-1} Cloud in the Central Molecular Zone

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We recently reported a population of protostellar candidates in the 20 km s^{-1} cloud in the Central Molecular Zone of the Milky Way, traced by H_2O masers in gravitationally bound dense cores. In this paper, we report high-angular-resolution ($\sim 3''$) molecular line studies of the environment of star formation in this cloud. Maps of various molecular line transitions as well as the continuum at 1.3 mm are obtained using the Submillimeter Array. Five NH_3 inversion lines and the 1.3 cm continuum are observed with the Karl G. Jansky Very Large Array. The interferometric observations are complemented with single-dish data. We find that the CH_3OH, SO, and HNCO lines, which are usually shock tracers, are better correlated spatially with the compact dust emission from dense cores among the detected lines. These lines also show enhancement in intensities with respect to SiO intensities toward the compact dust emission, suggesting the presence of slow shocks or hot cores in these regions. We find gas temperatures of $\gtrsim$100 K at 0.1-pc scales based on RADEX modelling of the H_2CO and NH_3 lines. Although no strong correlations between temperatures and linewidths/H_2O maser luminosities are found, in high-angular-resolution maps we notice several candidate shock heated regions offset from any dense cores, as well as signatures of localized heating by protostars in several dense cores. Our findings suggest that at 0.1-pc scales in this cloud star formation and strong turbulence may together affect the chemistry and temperature of the molecular gas.

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New Evidence for the Dynamical Decay of a Multiple System in the Orion Kleinmann-Low Nebula

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We have measured astrometry for members of the Orion Nebula Cluster with images obtained in 2015 with the Wide Field Camera 3 on board the Hubble Space Telescope. By comparing those data to previous measurements with NICMOS on Hubble in 1998, we have discovered that a star in the Kleinmann-Low Nebula, source x from Lonsdale et al. (1982), is moving with an unusually high proper motion of 29 mas yr^{-1}, which corresponds to 55 km s^{-1} at the distance of Orion. Previous radio observations have found that three other stars in the Kleinmann-Low Nebula (BN and sources I and n) have high proper motions (5–14 mas yr^{-1}) and were near a single location $\sim$540 years ago, and thus may have been members of a multiple system that dynamically decayed. The proper motion of source x is consistent with ejection from that same location 540 years ago, which provides strong evidence that the dynamical decay did occur and that the runaway star BN originated in the Kleinmann-Low Nebula rather than the nearby Trapezium cluster. However, our constraint on the motion of source n is significantly smaller than the most recent radio measurement, which indicates that it did not participate in the event that ejected the other three stars.

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The curious case of PDS 11: a nearby, >10 Myr old, classical T Tauri binary system

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We present results of our study of PDS 11 binary system, which belongs to a rare class of isolated, high galactic latitude T Tauri stars. Our spectroscopic analysis reveals that PDS 11 is a M2-M2 binary system with both components showing similar Hα emission strength. Both the components appear to be accreting, and are classical T Tauri stars. The lithium doublet Li I 6708 Å, a signature of youth, is present in the spectrum of PDS 11A, but not in PDS 11B. From the application of lithium depletion boundary age-dating method and a comparison with the Li I 6708 equivalent width distribution of moving groups, we estimated an age of 10–15 Myr for PDS 11A. Comparison with pre-main sequence evolutionary models indicates that PDS 11A is a 0.4 solar mass T Tauri star at a distance of 114–131 pc. PDS 11 system does not appear to be associated with any known star forming regions or moving groups. PDS 11 is a new addition, after TWA 30 and LDS 5606, to the interesting class of old, dusty, wide binary classical T Tauri systems in which both components are actively accreting.

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Circumstellar disks and outflows in turbulent molecular cloud cores: possible formation mechanism for misaligned systems

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We investigate the formation of circumstellar disks and outflows subsequent to the collapse of molecular cloud cores with the magnetic field and turbulence. Numerical simulations are performed by using an adaptive mesh refinement to follow the evolution up to $\sim$ 1000 yr after the formation of a protostar. In the simulations, circumstellar disks are formed around the protostars; those in magnetized models are considerably smaller than those in nonmagnetized models, but their size increases with time. The models with stronger magnetic field tends to produce smaller disks. During evolution in the magnetized models, the mass ratios of a disk to a protostar is approximately constant at $\sim 1-10\%$. The circumstellar disks are aligned according to their angular momentum, and the outflows accelerate along the magnetic field on the $10-100$ au scale; this produces a disk that is misaligned with the outflow. The outflows are classified into two types: a magneto-centrifugal wind and a spiral flow. In the latter, because of the geometry, the axis of rotation is misaligned with the magnetic field. The magnetic field has an internal structure in the cloud cores, which also causes misalignment between the outflows and the magnetic field on the scale of the cloud core. The distribution of the angular momentum vectors in a core also has a non-monotonic internal structure. This should create a time-dependent accretion of angular momenta onto the circumstellar disk. Therefore, the circumstellar disks are expected to change their orientation as well as their sizes in the long-term evolutions.

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On the origin of the spiral morphology in the Elias 2-27 circumstellar disc

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

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New eruptive variable in the massive star-forming region associated with IRAS 18507+0121 source

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We report the discovery of a strong outburst of the embedded young stellar object (YSO), UKIDSS−J185318.36+012454.5, located in the star-forming region associated with IRAS 18507+0121 source and an ultracompact H II region GAL 034.4+00.23. Using the archival photometric data and images, we determined the amplitude and the epoch of the outburst as well as the evolution stage and the basic parameters of the object. According to the near and mid-infrared colors and spectral energy distribution, we classify the object as an intermediate mass young stellar object (YSO) with Class 0/I evolution stage. Apparently, the outburst started between May 2003 and April 2004. The amplitude of the outburst is at least $\Delta K_s = 5.0$ mag. The summation of the photometric and spectral data does not allow to classify UKIDSS−J185318.36+012454.5 as FUor or EXor. We can consider it as an eruptive variable with mixed characteristics or MNor type object.

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Which Stars are Ionizing the Orion Nebula?

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The common assumption that Theta1OriC is the dominant ionizing source for the Orion Nebula is critically examined. This assumption underlies much of the existing analysis of the nebula. In this paper we establish through comparison of the relative strengths of emission lines with expectations from Cloudy models and through the direction of the bright edges of proplyds that Theta2OriA which lies beyond the Bright Bar, also plays an important role. Theta1OriC does dominate ionization in the inner part of the Orion Nebula, but outside of the Bright Bar as far as the southeast boundary of the Extended Orion Nebula, Theta2OriA is the dominant source. In addition to identifying the ionizing star in sample regions, we were able to locate those portions of the nebula in 3-D. This analysis illustrates the power of MUSE spectral imaging observations in identifying sources of ionization in extended regions.

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Star Formation Under the Outflow: The Discovery of a Non-Thermal Jet from OMC-2 FIR 3 and its Relationship to the Deeply Embedded FIR 4 Protostar

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We carried out multiwavelength (0.7-5 cm), multiepoch (1994-2015) Very Large Array (VLA) observations toward the region enclosing the bright far-IR sources FIR 3 (HOPS 370) and FIR 4 (HOPS 108) in OMC-2. We report the detection of 10 radio sources, seven of them identified as young stellar objects. We image a well-collimated radio jet with a thermal free-free core (VLA 11) associated with the Class I intermediate-mass protostar HOPS 370. The jet presents several knots (VLA 12N, 12C, 12S) of non-thermal radio emission (likely synchrotron from shock-accelerated relativistic electrons) at distances of 7,500-12,500 au from the protostar, in a region where other shock tracers have been previously identified. These knots are moving away from the HOPS 370 protostar at 100 km/s. The Class 0 protostar HOPS 108, which itself is detected as an independent, kinematically decoupled radio source, falls in the path of these non-thermal radio knots. These results favor the previously proposed scenario where the formation of HOPS 108 has been triggered by the impact of the HOPS 370 outflow with a dense clump. However, HOPS 108 presents a large proper motion velocity of 30 km/s, similar to that of other runaway stars in Orion, whose origin would be puzzling within this scenario. Alternatively, an apparent proper motion could result because of changes in the position of the centroid of the source due to blending with nearby extended emission, variations in the source shape, and /or opacity effects.

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L483: Warm Carbon-Chain Chemistry Source Harboring Hot Corino Activity

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The Class 0 protostar, L483, has been observed in various molecular lines in the 1.2 mm band at a sub-arcsecond resolution with ALMA. An infalling-rotating envelope is traced by the CS line, while a very compact component with a broad velocity width is observed for the CS, SO, HNCO, NH_2CHO, and $HCOOCH_3$ lines. Although this source is regarded as the warm carbon-chain chemistry (WCCC) candidate source at a 1000 au scale, complex organic molecules characteristic of hot corinos such as NH_2CHO and $HCOOCH_3$ are detected in the vicinity of the protostar. Thus, both hot corino chemistry and WCCC are seen in L483. Although such a mixed chemical character source has been recognized as an intermediate source in previous single-dish observations, we here report the first spatially-resolved detection. A kinematic structure of the infalling-rotating envelope is roughly explained by a simple ballistic model with the protostellar mass of 0.1–0.2 $M_\odot$ and the radius of the centrifugal barrier (a half of the centrifugal radius) of 30–200 au, assuming the inclination angle of 80° (0° for a face-on). The broad line emission observed in the above molecules most likely comes from the disk component inside the centrifugal barrier. Thus, a drastic chemical change is seen around the centrifugal barrier.

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Supernova Driving. IV. The Star Formation Rate of Molecular Clouds

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We compute the star formation rate (SFR) in molecular clouds (MCs) that originate *ab initio* in a new, higher-resolution simulation of supernova-driven turbulence. Because of the large number of well-resolved clouds with self-consistent boundary and initial conditions, we obtain a large range of cloud physical parameters with realistic statistical distributions, an unprecedented sample of star-forming regions to test SFR models and to interpret observational surveys. We confirm the dependence of the SFR per free-fall time, $SFR_{\rm ff}$, on the virial parameter, $\alpha_{\rm vir}$, found in previous simulations, and compare a revised version of our turbulent fragmentation model with the numerical results. The dependences on Mach number, $\mathcal{M}$, gas to magnetic pressure ratio, β, and compressive to solenoidal power ratio, χ at fixed $\alpha_{\rm vir}$ are not well constrained, because of random scatter due to time and cloud-to-cloud variations in $SFR_{\rm ff}$. We find that $SFR_{\rm ff}$ in MCs can take any value in the range $0 \leq SFR_{\rm ff} \lesssim 0.2$, and its probability distribution peaks at a value $SFR_{\rm ff} \approx 0.025$, consistent with observations. The values of $SFR_{\rm ff}$ and the scatter in the $SFR_{\rm ff}$–$\alpha_{\rm vir}$ relation are consistent with recent measurements in nearby MCs and in clouds near the Galactic center. Although not explicitly modeled by the theory, the scatter is consistent with the physical assumptions of our revised model and may also result in part from a lack of statistical equilibrium of the turbulence, due to the transient nature of MCs.

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Low-mass young stellar population and star formation history of the cluster IC 1805 in the W4 HII region

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W4 is a giant HII region ionized by the OB stars of the cluster IC 1805. The HII region/cluster complex has been a subject of numerous investigations as it is an excellent laboratory for studying the feedback effect of massive stars on the surrounding region. However, the low-mass stellar content of the cluster IC 1805 remains poorly studied till now. With the aim to unravel the low-mass stellar population of the cluster, we present the results of a multiwavelength study based on deep optical data obtained with the Canada-France-Hawaii Telescope, infrared data from 2MASS, Spitzer Space Telescope and X-ray data from Chandra Space Telescope. The present optical dataset is complete enough to detect stars down to 0.2 $M_\odot$, which is the deepest optical observations so far for the cluster. We identified 384 candidate young stellar objects (YSOs; 101 Class I/II and 283 Class III) within the cluster using various colour-colour and colour-magnitude diagrams. We inferred the mean age of the identified YSOs to be ∼2.5 Myr and mass in the range 0.3–2.5 $M_\odot$. The mass function of our YSO sample has a power law index of -1.23 ± 0.23, close to the Salpeter value (-1.35), and consistent with those of other star-forming complexes. We explored the disk evolution of the cluster members and found that the diskless sources are relatively older compared to the disk bearing YSO candidates. We examined the effect of high-mass stars on the circumstellar disks and found that within uncertainties, the influence of massive stars on the disk fraction seems to be insignificant. We also studied the spatial correlation of the YSOs with the distribution of gas and dust of the complex to conclude that IC 1805 would have formed in a large filamentary cloud.

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On the methanol emission detection in the TW Hya disc: the role of grain surface chemistry and non-LTE excitation

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The recent detection of gas-phase methanol (CH_3OH) lines in the disc of TW Hya by Walsh et al. provided the first observational constraints on the complex O-bearing organic content in protoplanetary discs. The emission has a ring-like morphology, with a peak at $\sim 30-50$ au and an inferred column density of $\sim$ 3–6 $\times 10^{12}$ cm^{-2}. A low CH_3OH fractional abundance of $\sim$ 0.3–4 $\times 10^{-11}$ (with respect to H_2) is derived, depending on the assumed vertical location of the CH_3OH molecular layer. In this study, we use a thermo-chemical model of the TW Hya disc, coupled with the ALCHEMIC gas-grain chemical model, assuming laboratory-motivated, fast diffusivities of the surface molecules to interpret the CH_3OH detection. Based on this disc model, we performed radiative transfer calculations with the LIME code and simulations of the observations with the CASA simulator. We found that our model allows to reproduce the observations well. The CH_3OH emission in our model appears as a ring with radius of $\sim$ 60 au. Synthetic and observed line flux densities are equal within the rms noise level of observations. The synthetic CH_3OH spectra calculated assuming local thermodynamic equilibrium (LTE) can differ by up to a factor of 3.5 from the non-LTE spectra. For the strongest lines, the differences between LTE and non-LTE flux densities are very small and practically negligible. Variations in the diffusivity of the surface molecules can lead to variations of the CH_3OH abundance and, therefore, line flux densities by an order of magnitude.

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Dynamical histories of the IC348 and NGC1333 star-forming regions in Perseus

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We present analyses of the spatial distributions of stars in the young (1–3 Myr) star-forming regions IC348 and NGC1333 in the Perseus Giant Molecular Cloud. We quantify the spatial structure using the Q-parameter and find that both IC348 and NGC1333 are smooth and centrally concentrated with Q-parameters of 0.98 and 0.89 respectively. Neither region exhibits mass segregation ($\Lambda_{\rm MSR} = 1.1^{+0.2}_{-0.3}$ for IC348 and $\Lambda_{\rm MSR} = 1.2^{+0.4}_{-0.3}$ for NGC1333, where $\Lambda_{\rm MSR} \sim 1$ corresponds to no mass segregation), nor do the most massive stars reside in areas of enhanced stellar surface density compared to the average surface density, according to the $\Sigma_{\rm LDR}$ method.
We then constrain the dynamical histories and hence initial conditions of both regions by comparing the observed values to N-body simulations at appropriate ages. Stars in both regions likely formed with sub-virial velocities which contributed to merging of substructure and the formation of smooth clusters. The initial stellar densities were no higher than $\rho \sim 100$–$500\ M_\odot\ {\rm pc}^{-3}$ for IC348 and $\rho \sim 500$–$2000\ M_\odot\ {\rm pc}^{-3}$ for NGC1333. These initial densities, in particular that of NGC1333, are high enough to facilitate dynamical interactions which would likely affect ∼10 per cent of protoplanetary discs and binary stars.

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Size and density sorting of dust grains in SPH simulations of protoplanetary discs

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The size and density of dust grains determine their response to gas drag in protoplanetary discs. Aerodynamical (size × density) sorting is one of the proposed mechanisms to explain the grain properties and chemical fractionation of chondrites. However, the efficiency of aerodynamical sorting and the location in the disc in which it could occur are still unknown. Although the effects of grain sizes and growth in discs have been widely studied, a simultaneous analysis including dust composition is missing. In this work we present the dynamical evolution and growth of multicomponent dust in a protoplanetary disc using a 3D, two-fluid (gas+dust) Smoothed Particle Hydrodynamics (SPH) code. We find that the dust vertical settling is characterised by two phases: a density-driven phase which leads to a vertical chemical sorting of dust and a size-driven phase which enhances the amount of lighter material in the midplane. We also see an efficient radial chemical sorting of the dust at large scales. We find that dust particles are aerodynamically sorted in the inner disc. The disc becomes sub-solar in its Fe/Si ratio on the surface since the early stage of evolution but sub-solar Fe/Si can be also found in the outer disc-midplane at late stages. Aggregates in the disc mimic the physical and chemical properties of chondrites, suggesting that aerodynamical sorting played an important role in determining their final structure.

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A Multi-Wavelength Analysis of Dust and Gas in the SR 24S Transition Disk

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We present new Atacama Large Millimeter/sub-millimeter Array (ALMA) 1.3 mm continuum observations of the SR 24S transition disk with an angular resolution $\lesssim$0.18″ (12 au radius). We perform a multi-wavelength investigation by combining new data with previous ALMA data at 0.45 mm. The visibilities and images of the continuum emission at the two wavelengths are well characterized by a ring-like emission. Visibility modeling finds that the ring-like emission is narrower at longer wavelengths, in good agreement with models of dust trapping in pressure bumps, although there are complex residuals that suggest potentially asymmetric structures. The 0.45 mm emission has a shallower profile inside the central cavity than the 1.3 mm emission. In addition, we find that the ^{13}CO and C^{18}O (J=2-1) emission peaks at the center of the continuum cavity. We do not detect either continuum or gas emission from the northern companion to this system (SR 24N), which is itself a binary system. The upper limit for the dust disk mass of SR 24N is $\lesssim 0.12\,M_{\bigoplus}$, which gives a disk mass ratio in dust between the two components of $M_{\mathrm{dust,SR\,24S}}/M_{\mathrm{dust,SR\,24N}} \gtrsim 840$. The current ALMA observations may imply that either planets have already formed in the SR 24N disk or that dust growth to mm-sizes is inhibited there and that only warm gas, as seen by ro-vibrational CO emission inside the truncation radii of the binary, is present.

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The star formation law in Galactic high-mass star-forming molecular clouds

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We study the star formation (SF) law in 12 Galactic molecular clouds with ongoing high-mass star formation (HMSF) activity, as traced by the presence of a bright IRAS source and other HMSF tracers. We define the molecular cloud (MC) associated to each IRAS source using ^{13}CO line emission, and count the young stellar objects (YSOs) within these clouds using GLIMPSE and MIPSGAL 24 μm Spitzer databases.The masses for high luminosity YSOs (Lbol>10 L$_{\odot}$) are determined individually using Pre Main Sequence evolutionary tracks and the evolutionary stages of the sources, whereas a mean mass of 0.5 M$_{\odot}$ was adopted to determine the masses in the low luminosity YSO population. The star formation rate surface density (Σ_{SFR}) corresponding to a gas surface density (Σ_{Gas}) in each MC is obtained by counting the number of the YSOs within successive contours of ^{13}CO line emission. We find a break in the relation between Σ_{SFR} and Σ_{Gas}, with the relation being power-law ($\Sigma_{\mathrm{SFR}} \propto \Sigma_{\mathrm{SFR}}^{\mathrm{N}}$) with the index N varying between 1.4 and 3.6 above the break. The Σ_{Gas} at the break is between 150-360 M$_{\odot}$ pc^{-2} for the sample clouds, which compares well with the threshold gas density found in recent studies of Galactic star-forming regions. Our clouds treated as a whole lie between the Kennicutt (1998) relation and the linear relation for Galactic and extra-galactic dense star-forming

regions. We find a tendency for the high-mass YSOs to be found preferentially in dense regions at densities higher than 1200 $M_\odot$ pc^{-2} ($\sim$ 0.25 g cm^2).

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Time Dependent Models of Magnetospheric Accretion onto Young Stars

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Accretion onto Classical T Tauri stars is thought to take place through the action of magnetospheric processes, with gas in the inner disk being channeled onto the star's surface by the stellar magnetic field lines. Young stars are known to accrete material in a time-variable manner and the source of this variability remains an open problem, particularly on the shortest ($\sim$ day) timescales. Using one-dimensional time-dependent numerical simulations that follow the field line geometry, we find that for plausibly realistic young stars, steady-state transonic accretion occurs naturally in the absence of any other source of variability. However, we show that if the density in the inner disk varies smoothly in time with $\sim$ day long time-scales (e.g., due to turbulence) this complication can lead to the development of shocks in the accretion column. These shocks propagate along the accretion column and ultimately hit the star, leading to rapid, large amplitude changes in the accretion rate. We argue that when these shocks hit the star the observed time-dependence will be a rapid increase in accretion luminosity followed by a slower decline and could be an explanation for some of the short period variability observed in accreting young stars. Our one-dimensional approach bridges previous analytic work to more complicated, multi-dimensional simulations, and observations.

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A modular set of synthetic spectral energy distributions for young stellar objects

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In this paper, I present a new set of synthetic spectral energy distributions (SEDs) for young stellar objects (YSOs) spanning a wide range of evolutionary stages, from the youngest deeply embedded protostars to pre-main-sequence stars with few or no disks. These models include significant improvements on the previous generation of published models: in particular, the new models cover a much wider and more uniform region of parameter space, do not include highly model-dependent parameters, and include a number of improvements that make them more suited to modelling far-infrared and sub-mm observations of forming stars. Rather than all being part of a single monolithic set of models, the new models are split up into sets of varying complexity. The aim of the new set of models is not to provide the most physically realistic models for young stars, but rather to provide deliberately simplified models for initial modelling, which allows a wide range of parameter space to be explored. I present the design of the model set, and show examples of fitting these models to real observations to show how the new grid design can help us better understand what can be determined from limited unresolved observations. The models, as well as a Python-based fitting tool are publicly available to the community.

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JVLA Observations of Young Brown Dwarfs

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We present sensitive 3.0 cm JVLA radio continuum observations of six regions of low-mass star formation that include twelve young brown dwarfs and four young brown dwarf candidates. We detect a total of 49 compact radio sources in the fields observed, of which 24 have no reported counterparts and are considered new detections. Twelve of the radio sources show variability in timescales of weeks to months, suggesting gyrosynchrotron emission produced in active magnetospheres. Only one of the target brown dwarfs, FU Tau A, was detected. However, we detected radio emission associated with two of the brown dwarf candidates, WL 20S and CHLT 2. The radio flux densities of the sources associated with these brown dwarf candidates are more than an order of magnitude larger than expected for a brown dwarf and suggest a revision of their classification. In contrast, FU Tau A falls on the well-known correlation between radio luminosity and bolometric luminosity, suggesting that the emission comes from a thermal jet and that this brown dwarf seems to be forming as a scaled-down version of low-mass stars.

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Helium Ionization in the Diffuse Ionized Gas surrounding UCHII regions

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We present measurements of the singly ionized helium to hydrogen ratio (n_{He^+}/n_{H^+}) toward diffuse gas surrounding three Ultra-Compact H II (UCH II) regions: G10.15-0.34, G23.46-0.20 & G29.96-0.02. We observe radio recombination lines (RRLs) of hydrogen and helium near 5 GHz using the GBT to measure the n_{He^+}/n_{H^+} ratio. The measurements are motivated by the low helium ionization observed in the warm ionized medium (WIM) and in the inner Galaxy diffuse ionized regions (DIR). Our data indicate that the helium is not uniformly ionized in the three observed sources. Helium lines are not detected toward a few observed positions in sources G10.15-0.34 & G23.46-0.20 and the upper limits of the n_{He^+}/n_{H^+} ratio obtained are 0.03 and 0.05 respectively. The selected sources harbor stars of type O6 or hotter as indicated by helium line detection toward the bright radio continuum emission from the sources with mean n_{He^+}/n_{H^+} value 0.06±0.02. Our data thus show that helium in diffuse gas located a few pc away from the young massive stars embedded in the observed regions is not fully ionized. We investigate the origin of the non-uniform helium ionization and rule out the possibilities : (a) that the helium is doubly ionized in the observed regions and (b) that the low n_{He^+}/n_{H^+} values are due to additional hydrogen ionizing radiation produced by accreting low-mass stars (Smith 2014). We find that selective absorption of ionizing photons by dust can result in low helium ionization but needs further investigation to develop a self-consistent model for dust in H II regions.

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Constraining proto-planetary disc evolution using accretion rate and disc mass measurements: the usefulness of the dimensionless accretion parameter

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We explore how measurements of protoplanetary disc masses and accretion rates provided by surveys of star forming regions can be analysed via the dimensionless accretion parameter, which we define as the product of the accretion rate and stellar age divided by the disc mass. By extending and generalising the study of Jones et al. (2012), we demonstrate that this parameter should be less than or of order unity for a wide range of evolutionary scenarios, rising above unity only during the final stages of outside in clearing by external photoevaporation. We use this result to assess the reliability of disc mass estimates derived from CO isotopologues and submm continuum emission by examining the distribution of accretion efficiencies in regions which are not subject to external photoevaporation. We find that while dust based mass estimates produce results compatible with theoretical expectations assuming canonical dust/gas ratio, the systematically lower CO based estimates yield accretion efficiencies significantly above unity in contrast with the theory. This finding provides additional evidence that CO based disc masses are an under-estimate, in line with arguments that have been made on the basis of chemical modelling of relatively small samples. On the other hand, we demonstrate that dust based mass estimates are sufficiently accurate to reveal distinctly higher accretion efficiencies in the Trapezium cluster, where this result is expected given the evident importance of external photoevaporation. We therefore propose the dimensionless accretion parameter as a new diagnostic of external photoevaporation in other star forming regions.

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The ALMA Early Science View of FUor/EXor objects. III. The Slow and Wide Outflow of V883 Ori

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We present Atacama Large Millimeter/ sub-millimeter Array (ALMA) observations of V883 Ori, an FU Ori object. We describe the molecular outflow and envelope of the system based on the ^{12}CO and ^{13}CO emissions, which together trace a bipolar molecular outflow. The C^{18}O emission traces the rotational motion of the circumstellar disk. From the ^{12}CO blue-shifted emission, we estimate a wide opening angle of $\sim$150° for the outflow cavities. Also, we find that the outflow is very slow (characteristic velocity of only 0.65 km s^{-1}), which is unique for an FU Ori object. We calculate the kinematic properties of the outflow in the standard manner using the ^{12}CO and ^{13}CO emissions. In addition, we present a P Cygni profile observed in the high-resolution optical spectrum, evidence of a wind driven by the accretion and being the cause for the particular morphology of the outflows. We discuss the implications of our findings and the rise of these slow outflows during and/or after the formation of a rotationally supported disk.

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A 2MASS/AllWISE Search for Extremely Red L Dwarfs – The Discovery of Several Likely L Type Members of β Pic, AB Dor, Tuc-Hor, Argus, and the Hyades

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Young brown dwarfs share many properties with directly imaged giant extrasolar planets. They therefore provide unique laboratories for investigating the full range of temperature and mass encompasses by the growing collection of planets discovered outside our Solar System. Furthermore, if they can be tied to a particular group of coeval stars, they also provide vital anchor points for low-mass empirical isochrones. We have developed a novel procedure for identifying such objects based on their unique 2MASS and AllWISE colors. Using our search criteria, we have identified 50 new, late-type L dwarf candidates, 47 of which are spectroscopically confirmed as L dwarfs with follow-up near-infrared spectroscopy. We evaluate the potential membership of these objects in nearby, young moving groups using their proper motions, photometric distance estimates, and spectroscopic indicators of youth, and find seven likely L-type members belonging to the β Pictoris moving group, the AB Doradus moving group, the Tucana-Horologium association, or the Argus association, in addition to several lower probability members. Also found are two late-type (L5 and L6) potential members of the nearby Hyades cluster (WISEA J043642.75+190134.8 and WISEA J044105.56+213001.5).

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Connecting HL Tau to the Observed Exoplanet Sample

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The Atacama Large Millimeter/submilimeter Array (ALMA) recently revealed a set of nearly concentric gaps in the protoplanetary disk surrounding the young star HL Tau. If these are carved by forming gas giants, this provides the first set of orbital initial conditions for planets as they emerge from their birth disks. Using N-body integrations, we have followed the evolution of the system for 5 Gyr to explore the possible outcomes. We find that HL Tau initial conditions scaled down to the size of typically observed exoplanet orbits naturally produce several populations in the observed exoplanet sample. First, for a plausible range of planetary masses, we can match the observed eccentricity distribution of dynamically excited radial velocity giant planets with eccentricities > 0.2. Second, we roughly obtain the observed rate of hot Jupiters around FGK stars. Finally, we obtain a large efficiency of planetary ejections of $\approx$2 per HL Tau-like system, but the small fraction of stars observed to host giant planets makes it hard to match the rate of free-floating planets inferred from microlensing observations. In view of upcoming GAIA results, we also provide predictions for the expected mutual inclination distribution, which is significantly broader than the absolute inclination distributions typically considered by previous studies.

Accepted by MNRAS

http://arxiv.org/pdf/1703.09132

XMM-Newton X-ray Observations of LkCa 15: A T Tauri Star With a Formative Planetary System

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High-resolution ground-based images of the T Tauri star LkCa 15 have revealed multiple companions that are thought to comprise a formative planetary system. The candidate protoplanets orbit at distances ≈15 - 20 AU within the dust-depleted inner region of the circumstellar disk. Because of its young age (1 - 4 Myr), LkCa 15 provides a benchmark system for testing planet-formation models. We detected LkCa 15 as a bright X-ray source in a short 10 ks Chandra observation in 2009. We report here new results obtained from a deeper 37 ks XMM-Newton observation in 2014. The new data provide better sampling in the time domain and improved sensitivity at low energies below 1 keV. Spectral fits with thermal emission models require at least two temperature components at $kT_{cool} \approx 0.4$ keV and $kT_{hot} \approx 2.2$ keV. The value of kT_{hot} is about a factor of two less than inferred from Chandra, suggesting that the hot-component temperature is variable. The best-fit absorption column density is in good agreement with that expected from optical extinction estimates $A_V = 1.3 - 1.7$ mag. The intrinsic X-ray luminosity is $L_x(0.2 - 10$ keV$) =$ 3e30 ergs s^{-1}. Estimates of the X-ray heating rate of the inner disk and protoplanets are sensitive to the assumed disk gas surface density for which recent ALMA observations give estimates $\Sigma_{0,gas} \sim 100$ g cm^{-2} at 1 AU from the star. At such densities, X-ray heating is confined mainly to the upper disk layers and X-ray penetration through the disk midplane to the protoplanets at r ≈ 15 - 20 AU is negligible.

Accepted by ApJ

https://arxiv.org/pdf/1703.06860

Rings and gaps produced by variable magnetic disk winds and avalanche accretion streams: I. Axisymmetric resistive MHD simulations

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Rings and gaps are being observed in an increasing number of disks around young stellar objects. We illustrate the formation of such radial structures through idealized, 2D (axisymmetric) resistive MHD simulations of coupled disk-wind systems threaded by a relatively weak poloidal magnetic field (plasma-$\beta \sim 10^3$). We find two distinct modes of accretion depending on the resistivity and field strength. A small resistivity or high field strength promotes the development of rapidly infalling 'avalanche accretion streams' in a vertically extended disk envelope that dominates the dynamics of the system, especially the mass accretion. The streams are suppressed in simulations with larger resistivities or lower field strengths, where most of the accretion instead occurs through a laminar disk. In these simulations, the disk accretion is driven mainly by a slow wind that is typically accelerated by the pressure gradient from a predominantly toroidal magnetic field. Both wind-dominated and stream-dominated modes of accretion create prominent features in the surface density distribution of the disk, including rings and gaps, with a strong spatial variation of the magnetic flux relative to the mass. Regions with low mass-to-flux ratios accrete quickly, leading to the development of gaps, whereas regions with higher mass-to-flux ratios tend to accrete more slowly, allowing matter to accumulate and form dense rings. In some cases, avalanche accretion streams are observed to produce dense rings directly through continuous feeding. We discuss the implications of ring and gap formation driven by winds and streams on grain growth and planet formation.

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https://arxiv.org/pdf/1702.01565

OH Survey along Sightlines of Galactic Observations of Terahertz C+

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We have obtained OH spectra of four transitions in the $^2\Pi_{3/2}$ ground state, at 1612, 1665, 1667, and 1720 MHz, toward 51 sightlines that were observed in the *Herschel* project Galactic Observations of Terahertz C+. The observations cover the longitude range of (32°, 64°) and (189°, 207°) in the northern Galactic plane. All of the diffuse OH emissions conform to the so-called 'Sum Rule' of the four brightness temperatures, indicating optically thin emission conditions for OH from diffuse clouds in the Galactic plane. The column densities of the HI 'halos' N(HI) surrounding molecular clouds increase monotonically with OH column density, $N(\mathrm{OH})$, until saturating when $N(HI) = 1.0 \times 10^{21}$ cm^{-2} and $N(\mathrm{OH}) \gtrsim 4.5 \times 10^{15}$ cm^{-2}, indicating the presence of molecular gas that cannot be traced by HI. Such a linear correlation, albeit weak, is suggestive of HI halos' contribution to the UV shielding required for molecular formation. About 18% of OH clouds have no associated CO emission (CO-dark) at a sensitivity of 0.07 K but are associated with C^+ emission. A weak correlation exists between C^+ intensity and OH column density for CO-dark molecular clouds. These results imply that OH seems to be a better tracer of molecular gas than CO in diffuse molecular regions.

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https://arxiv.org/pdf/1703.05864

Planet Formation in AB Aurigae: Imaging of the inner gaseous Spirals observed inside the Dust Cavity

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We report the results of ALMA observations of a protoplanetary disk surrounding the Herbig Ae star AB Aurigae. We obtained high-resolution (0.1"; 14 au) images in ^{12}CO (J=2-1) emission and in dust continuum at the wavelength of 1.3 mm. The continuum emission is detected at the center and at the ring with a radius of $\sim$ 120 au. The CO emission is dominated by two prominent spirals within the dust ring. These spirals are trailing and appear to be about 4 times brighter than their surrounding medium. Their kinematics is consistent with Keplerian rotation at an inclination of 23^o. The apparent two-arm-spiral pattern is best explained by tidal disturbances created by an unseen companion

located at 60–80 au, with dust confined in the pressure bumps created outside this companion orbit. An additional companion at r of 30 au, coinciding with the peak CO brightness and a large pitch angle of the spiral, would help to explain the overall emptiness of the cavity. Alternative mechanisms to excite the spirals are discussed. The origin of the large pitch angle detected here remain puzzling.

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http://arxiv.org/pdf/1704.02699

The earliest phases of high-mass star formation, as seen in NGC 6334 by Herschel

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To constrain models of high-mass star formation, the *Herschel*/HOBYS key program aims at discovering massive dense cores (MDCs) able to host the high-mass analogs of low-mass prestellar cores, which have been searched for over the past decade. We here focus on NGC 6334, one of the best-studied HOBYS molecular cloud complexes.
We used *Herschel* PACS and SPIRE $70-500$ μm images of the NGC 6334 complex complemented with (sub)millimeter and mid-infrared data. We built a complete procedure to extract $\sim$0.1 pc dense cores with the *getsources* software, which simultaneously measures their far-infrared to millimeter fluxes. We carefully estimated the temperatures and masses of these dense cores from their spectral energy distributions (SEDs). We also identified the densest pc-scale cloud structures of NGC 6334, one 2 pc $\times$ 1 pc ridge and two 0.8 pc $\times$ 0.8 pc hubs, with volume-averaged densities of $\sim 10^5$ cm^{-3}.
A cross-correlation with high-mass star formation signposts suggests a mass threshold of 75 $M_\odot$ for MDCs in NGC 6334. MDCs have temperatures of $9.5-40$ K, masses of $75-1000$ $M_\odot$, and densities of $1\times10^5 - 7\times10^7$ cm^{-3}. Their mid-infrared emission is used to separate 6 IR-bright and 10 IR-quiet protostellar MDCs while their 70 μm emission strength, with respect to fitted SEDs, helps identify 16 starless MDC candidates. The ability of the latter to host high-mass prestellar cores is investigated here and remains questionable. An increase in mass and density from the starless to the IR-quiet and IR-bright phases suggests that the protostars and MDCs simultaneously grow in mass. The statistical lifetimes of the high-mass prestellar and protostellar core phases, estimated to be $1-7\times~10^4$ yr and at most $3\times~10^5$ yr respectively, suggest a dynamical scenario of high-mass star formation.
The present study provides good mass estimates for a statistically significant sample, covering the earliest phases of high-mass star formation. High-mass prestellar cores may not exist in NGC 6334, favoring a scenario presented here, which simultaneously forms clouds and high-mass protostars.

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http://arxiv.org/pdf/1703.09839

Formation of wide binary stars from adjacent cores

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Wide gravitationally bound pairs of stars can be formed from adjacent prestellar cores that happen to move slowly enough relative to each other. These binaries are remnants of the primordial clustering. It is shown that the expected fraction of wide bound pairs in low-density star formation regions can be larger than the fraction of wide pairs in the field. On the other hand, wide binaries do not form or survive in dense clusters. Recent works on the separation distribution of young binaries, summarized here, confirm these expectations. Alternative formation mechanisms of wide binaries such as cluster dissolution or unfolding of triple stars cannot explain the large observed fraction of young

wide pairs and therefore are not dominant. The fact that more than a half of wide pairs contain subsystems matches the general multiplicity statistics and does not imply that hierarchical multiplicity and wide binaries are genetically related.

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Predicting radio emission from the newborn hot Jupiter V830 Tau b and its host star

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Magnetised exoplanets are expected to emit at radio frequencies analogously to the radio auroral emission of Earth and Jupiter. Here, we predict the radio emission from V830 Tau b, the youngest (2 Myr) detected exoplanet to date. We model the wind of its host star using three-dimensional magnetohydrodynamics simulations that take into account the reconstructed stellar surface magnetic field. Our simulations allow us to constrain the local conditions of the environment surrounding V830 Tau b that we use to then compute its radio emission. We estimate average radio flux densities of 6 to 24 mJy, depending on the assumption of the radius of the planet (one or two Jupiter radii). These radio fluxes are not constant along one planetary orbit, and present peaks that are up to twice the average values. We show here that these fluxes are weakly dependent (a factor of 1.8) on the assumed polar planetary magnetic field (10 to 100 G), opposed to the maximum frequency of the emission, which ranges from 18 to 240 MHz. We also estimate the thermal radio emission from the stellar wind. By comparing our results with the Karl G. Jansky Very Large Array and the Very Long Baseline Array observations of the system, we constrain the stellar mass-loss rate to be $< 3 \times 10^{-9}$ M$_\odot$ yr^{-1}, with likely values between $\sim 10^{-12}$ and 10^{-10} M$_\odot$ yr^{-1}. With these values, we estimate that the frequency-dependent extension of the radio-emitting wind is around ~ 3 to 30 stellar radii ($R_\star$) for frequencies in the range of 275 to 50 MHz, implying that V830 Tau b, at an orbital distance of 6.1 $R_\star$, could be embedded in the regions of the host star's wind that are optically thick to radio wavelengths, but not deeply so. We also note that planetary emission can only propagate in the stellar wind plasma if the frequency of the cyclotron emission exceeds the stellar wind plasma frequency. In other words, we find that for planetary radio emission to propagate through the host star wind, planetary magnetic field strengths larger than ~ 1.3 to 13 G are required. Since our radio emission computations are based on analogies with solar system planets, we caution that our computations should be considered as estimates. Nevertheless, the V830 Tau system is a very interesting system for conducting radio observations from both the perspective of radio emission from the planet as well as from the host star's wind.

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https://arxiv.org/pdf/1703.03622

The impact of non-ideal magnetohydrodynamics on binary star formation

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We investigate the effect of non-ideal magnetohydrodynamics (MHD) on the formation of binary stars using a suite of three-dimensional smoothed particle magnetohydrodynamics simulations of the gravitational collapse of 1 M$_\odot$, rotating, perturbed molecular-cloud cores. Alongside the role of Ohmic resistivity, ambipolar diffusion and the Hall effect, we also examine the effects of magnetic field strength, orientation and amplitude of the density per- turbation. When modelling sub-critical cores, ideal MHD models do not collapse whereas non-ideal MHD models collapse to form single protostars. In supercritical ideal MHD models, increasing the magnetic field strength or decreasing the initial-density perturbation amplitude decreases the initial binary separation. Strong magnetic fields initially perpendicular to the rotation axis suppress the formation of binaries and yield discs with magnetic fields $\sim$10 times stronger than if

the magnetic field was initially aligned with the rotation axis. When non-ideal MHD is included, the resulting discs are larger and more massive, and the binary forms on a wider orbit. Small differences in the supercritical cores caused by non-ideal MHD effects are amplified by the binary interaction near periastron. Overall, the non-ideal effects have only a small impact on binary formation and early evolution, with the initial conditions playing the dominant role.

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https://arxiv.org/pdf/1612.02016

A comprehensive study of young B stars in NGC 2264: I. Space photometry and asteroseismology

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Space photometric time series of the most massive members of the young open cluster NGC 2264 allow us to study their different sources of variability down to the millimagnitude level and permits a search for Slowly Pulsating B (SPB) type pulsation among objects that are only a few million years old. Our goal is to conduct a homogeneous study of young B type stars in the cluster NGC 2264 using photometric time series from space in combination with high-resolution spectroscopy and spectropolarimetry obtained from the ground. The latter will be presented in a separate follow-up article. We performed frequency analyses for eleven B stars in the field of the young cluster NGC 2264 using photometric time series from the MOST, CoRoT and Spitzer space telescopes and the routines Period04 and SigSpec. We employ the MESA stellar evolution code in combination with the oscillation code GYRE to identify the pulsation modes for two SPB stars which exhibit short period spacing series. From our analysis we identify four objects that show SPB pulsations, five stars that show rotational modulation of their light curves caused by spots, one star that is identified to be a binary, and one object in the field of the cluster that is found to be a non-member Be star. In two SPB stars we detect a number of regularly spaced pulsation modes that are compatible with being members of a g mode period series. Despite NGC 2264's young age, our analysis illustrates that its B type members have already arrived on the zero-age main sequence (ZAMS). Our asteroseismic analysis yields masses between 4 and 6 Msun and ages between 1 and 6 million years, which agree well to the overall cluster age.

Accepted by A&A

http://arxiv.org/pdf/1703.06456

New Jobs

Postdoctoral Fellowship at NRC Herzberg in Planet Formation

We seek an excellent researcher with observational expertise using the Atacama Large Millimeter Array (ALMA) for a postdoctoral fellowship in the field of planet formation. The fellowship will be held at the National Research Council of Canada's Herzberg Programs in Astronomy and Astrophysics (NRC-Herzberg) located in Victoria, BC, Canada. To enable widespread use of ALMA data, NRC-Herzberg has begun a new initiative to adapt ALMA data reduction to the distributed Canadian Advanced Network for Astronomical Research (CANFAR) supported by NRC Herzberg's Canadian Astronomy Data Centre (CADC). The successful candidate will avail themselves of the powerful CANFAR resources and ALMA data to pursue planet formation studies. If interested in this position, please contact James Di Francesco (james.difrancesco@nrc-cnrc.gc.ca) or Brenda Matthews (brenda.matthews@nrc-cnrc.gc.ca) for further details. Applications must be made by April 23, 2017 at http://tinyurl.com/nrcpdfpf2017.

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.

Meetings

Galactic Star Formation with Surveys

Haus der Astronomie, Heidelberg, Germany, 3.-7. July 2017

Explaining the physical processes that give rise to the star formation rates and efficiencies of the interstellar medium remains a key open topic in modern astrophysics. The multi-scale nature of star formation presents challenges to investigators. Phenomena relevant to star formation span from the scales of individual stars up to entire galaxies. This, in turn, gives rise to the multi-physics nature of star formation: self-gravity of gas, turbulence, thermal physics, chemical processes, magnetic fields, and Galactic environment are all crucial factors affecting the gas-to-stars conversion.

As a result of this complexity, obtaining a holistic picture of star formation physics requires systematic studies at all scales relevant for star formation. And indeed during the past decade, the star formation community has strongly responded to the need for systematic studies. Wide-field surveys, all-sky missions, and surveys targeting large samples have been performed at most wavelengths relevant for star formation studies. The scientific exploitation of these surveys is only in the beginning.

Today, the large observational programs enable us to address various aspects of star formation physics with statistically interesting samples, in volumes relevant for Galactic star formation. Similarly at the side of theoretical works, the ever-increasing computing power is enabling an era in which the internal properties of dense gas clouds can be studied in Galaxy-scale setups. Together, these advances allow us to start probing the impact of Galactic environment on the properties of star-forming gas, and from therein, to understand the difference between local and global drivers of star formation in galaxies.

The 6th MPIA Summer Conference, 'Galactic Star Formation with Surveys', is dedicated to bringing together scientists who work on understanding the star-forming properties of the interstellar medium at Galactic scales and/or with the help of modern survey data. In general, the topics will cover:

1) Galaxy-scale surveys addressing the star-forming content and -potential of the Milky Way; the global properties and structure of the atomic and molecular gas in the Milky Way.

2) (Wide-field) surveys of nearby molecular clouds and their atomic components targeting especially the diagnostics of molecular cloud formation and evolution.

3) Theoretical works focusing on the formation and evolution of molecular clouds in the Galactic context, emphasising the connection of such works with the observational surveys.

For further information, see the conference web-site:
http://www.mpia.de/homes/sc2017/index.html

Abstract submission is open until 21st April (see the web-page for details).

Looking forward to a stimulating conference in Heidelberg!

SOC: Coryn Bailer-Jones, Clare Dobbs, Jennifer Hatchell, Patrick Hennebelle, Mark Heyer, Naomi McClure-Griffiths, Sergio Molinari, Friedrich Wyrowski

LOC: Jouni Kainulainen, Henrik Beuther, Aida Ahmadi, Roxana Chira, Marina Gilke, Manuel Riener, Miaomiao Zhang

Sponsored by SFB881 (http://sfb881.zah.uni-heidelberg.de).

Star Cluster Formation: Mapping the first few Myr's

14-15 June 2017, El Escorial, Spain

This workshop is hosted by the StarFormMapper (SFM) project, an EU Horizon2020 funded collaboration between the University of Leeds, University of Cardiff, University Grenoble Alps and Quasar Science Resources SL. Our aim is to combine state-of-the-art models with observations from ESA's Gaia and Herschel missions to map the density distribution of star formation regions, to constrain the mechanisms that underlie massive star and star cluster formation.

Combining observation and theory, this workshop will tackle the the big issues of this field, including: the clustering of stars and gas, the initial conditions required to form star clusters form and their early kinematic and dynamical evolution (sub-structure, mass segregation).

Programme

- Initial conditions of stellar cluster formation
- Spatial properties of star cluster forming regions
- Spatial Structure of newly formed star clusters
- Dynamics and evolution of newly formed star clusters
- Review on Gaia, its status and news

Invited speakers:

- Richard Parker (The University of Sheffield, UK)
- Nick Wright (Keele University, UK)
- Sarah Ragan (Cardiff University, UK)
- Michael Kuhn (Universidad de Valparaso, Chile)
- Jose Hernandez (ESA, Spain)

Scientific organizers

- Toby J. Moore (Chair) - Liverpool John Moors University
- Zeinab Khorrami - Cardiff University
- Anne Buckner - Leeds University
- Pouria Khalaj - Universite Grenoble Alpes

Local organizers

- Jose Maria Herrera (Chair)
- Luis Valero
- Ignacio de la Calle
- Patricia Grant

Weblink: http://sfm.leeds.ac.uk/madrid-workshop-2017/

Email: sfm2017@quasarsr.com

Summary of Upcoming Meetings

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

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

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

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

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

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

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

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

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

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

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

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

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