# THE STAR FORMATION NEWSLETTER

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

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# The Star Formation Newsletter



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

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## Cover Picture

IC 4628 = Gum 56 is an HII region in Scorpius excited by several OB stars. It is located at a distance of about 2000 pc. The image is part of the VPHAS+ survey using the VLT Survey Telescope at ESO's Paranal Observatory in Chile, see http://www.vphasplus.org.

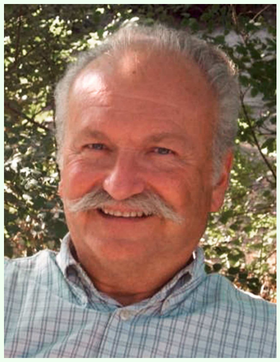
Image courtesy ESO.
Acknowledgment: Martin Pugh.

## 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

# Thierry Montmerle

*in conversation with Bo Reipurth*



**Q**: *What was your thesis about and who was your adviser?*

**A:** My thesis was – perhaps surprisingly for the readers of the SF Newsletter – about cosmology. And about a quite exotic topic: at that time, a diffuse $\gamma$-ray background had been discovered during an Earth-Moon coast by a detector aboard *Apollo-15* (1971), showing a bump around 1 MeV, and Floyd Stecker at NASA's Goddard Space Flight Center had proposed that the mechanism was redshifted $\pi^0$-decay by the $p\bar{p}$ reaction, in other words the annihiliation of matter and antimatter in the early universe ($z \sim 100$).

For my PhD I wanted to test an idea to explain the $\gamma$-ray background: instead of assuming $\pi^0$-decay from $p\bar{p}$ annihilation, why not assume $\pi^0$-decay from $pp$ collisions ? In other words, why not assume the existence of "cosmological cosmic rays", produced by shock waves from supernova explosions of (hypothetical) massive primordial stars ? Such cosmic rays produce $\gamma$-rays by colliding with matter at high energies (> GeV), but a low energies ($\sim$ MeV) they produce light elements (Li, Be, B) by p$\alpha$ and $\alpha\alpha$ reactions, so the idea interested very much Hubert Reeves, a renowned nuclear astrophysicist, and his colleagues at Saclay, because they were working on the hypothesis that such galactic cosmic-ray induced low-energy "spallation" reactions in the interstellar medium could explain the very low cosmic abundance of these light elements (compared to the neighbouring nuclei -this is now the accepted explanation). Also in Saclay, there was a team of instrumentalists developing the spark chamber detector aboard ESA's *COS-B* satellite (1975-1982), precisely to detect *galactic* $\gamma$-rays produced by $pp$ collisions of cosmic rays on interstellar matter –in particular molecular clouds. So I did some instrumental work on spark chambers (carried by pre-satellite balloon experiments), along with theoretical calculations on the implications of the "cosmological cosmic rays" hypothesis, with Hubert as my PhD thesis advisor.

This avenue proved very fruitful, with the publication of numerous ApJ articles (1975+), but it became increasingly clear that the $\gamma$-ray background was not diffuse, but the sum of unresolved sources, mostly AGNs, and the MeV bump mostly due to unresolved nuclear $\gamma$-ray lines produced by interplanetary cosmic rays in the detectors. So I had to drop the idea again ! Nevertheless, the story did not stop, because I used the same physics, not in a cosmological context, but in the Galaxy.

**Q**: *In the late 1970s you studied the association of cosmic rays with supernova remnants in OB associations. What were your conclusions, and how have they held up with time?*

**A:** This work was, somewhat paradoxically, a logical consequence of my thesis: when the first $\gamma$-ray sources were discovered by *COS-B*, I checked their positions (error boxes of $\sim 1^\circ$ or more !) with those of supernova remnants (SNR) and HII regions, and noted that over half of the $\sim$ 20 *COS-B* sources coincided (within errors !) with SNRs which themselves coincided with HII regions. The breakthrough was that the observed $\gamma$-ray luminosity implied a local cosmic-ray density at least an order of magnitude larger than average galactic cosmic rays. In other words, these coincidences supported the idea that *$\gamma$-ray cources were localized sites of cosmic-ray acceleration by SNRs.*

Then it was easy to adapt my "cosmological" scenario to actual *COS-B* sources: the HII regions were created by massive stars in OB associations, which in turn could explode as supernovae before the association would disperse (a few million years); at the time major advances were made in the theory of cosmic rays acceleration by shock waves (Axford, Bell, Blandford, Ostriker, etc., 1977, 1978+), supporting the view that cosmic rays could be accelerated in situ by those SNRs, and in our case collide with the molecular clouds giving birth to massive stars – thus giving rise to $\pi^0$-decay ($pp$) galactic $\gamma$-ray emission in the 1-100 GeV domain.

This rather simple-minded scenario, which I dubbed the "SNOB" scenario, has surprisingly well survived the successive generations of $\gamma$-ray satellites after *COS-B* (about one every decade): *Compton Gamma-Ray Observatory* (CGRO: 1991-2000), *Fermi* (launched in 2008), and now the ground-based Cerenkov observatories (*HESS*, started in 2004, *MAGIC*, started in 2005, etc.), which reach higher $\gamma$-ray energies ($> 1 - 10$ TeV) with a much improved angular resolution of $\sim 0.1^\circ$. The original 1979 paper continues to be regularly cited; "SNOB" sources still make up a significant fraction of $\gamma$-ray sources in the galactic plane, and are now considered as "laboratories" for the study of cosmic-ray acceleration by SNR shock waves.

**Q**: *In 1983 you and your collaborators presented the 'X-ray Christmas tree', a study of X-ray variability in the $\rho$ Ophiuchi cloud. What motivated that study?*

**A:** The starting point was the same as before: the interpretation of $\gamma$-ray sources discovered by *COS-B*. There was a source spatially coincident (again within a $\sim 1^\circ$ error box) with the nearby (160 pc) $\rho$ Ophiuchi cloud, that implied an excess cosmic-ray flux by a factor $\sim 2-3$ (with the cloud mass estimate of the time), but without known SNR. So we thought that perhaps a pulsar was the explanation of the $\gamma$-ray source, rather than cosmic rays, and we applied for observing time with the *Einstein* satellite, which had been launched a few years before, to look at the region in X-rays. The initial observation was actually split into several sessions for operational reasons, giving evidence for many strong variable sources; follow-up observations were subsequently obtained, separated by days and hours. The result was spectacular –and unexpected: analyzing each image separately, we discovered that there were actually many point X-ray sources associated with T Tauri stars, and that their X-ray flux was highly variable (hence the "Christmas tree", or "Xmas tree" !). A few years before, the Sun had been imaged in soft X-rays by *Skylab*, revealing full-disk coronal emission and flares in this energy range. Our *Einstein* results was consistent with T Tauri stars being the seat of an X-ray activity similar to that of the Sun -but enhanced by factors of up to a million !

A few individual T Tauri stars had been observed in X-rays by *Einstein* prior to our work, but our time-dependent observation of a cluster of X-ray variable T Tauri stars did trigger many subsequent observations of molecular clouds hosting young star clusters, in particular after *Einstein* with *ROSAT* (1990-1999). But then, what about the $\gamma$-ray emission from the $\rho$ Oph cloud seen by *COS-B* ? Well, it turned out eventually that the cloud mass had been underestimated (as a result of a revision of the $CO/H_2$ conversion factor), as well as the $\gamma$-ray flux itself (given the extent of the emitting region), so that the interpretation of $\gamma$-ray emission turned out to be "normal", i.e., similar to the standard cosmic-ray/interstellar matter interaction at work elsewhere in the Galaxy.

I should add at this stage that, with Eric Feigelson, we made follow-up observations of the $\rho$ Oph cloud with the Very Large Array (which had become operational shortly before, in 1980) at radio cm wavelengths, and we also discovered intense radio flares -but much less prominent than in X-rays. However, a very important *non-variable* radio source was discovered, which was subsequently named "VLA1623" (because of its position) and turned out to be a kind of prototype "Class 0" protostar.

**Q**: *Your student Philippe André and you presented an influential study in 1994 discussing the evolution of circumstellar material from protostars to T Tauri stars. What were the main conclusions?*

**A:** At the time of our *Einstein* observations, IR astronomy was still in its infancy, and mm telescopes were based on heterodyne receivers that could only detect molecular lines (CO, etc.). So circumstellar dust around young, cool stars like T Tauri stars was poorly known: "warm" dust (close to the star) was accessible through near- to mid-IR continuum observations, and led to the famous Class I-III T Tauri star classification introduced by Charlie Lada, but cold dust, accessible only in the submm-mm domain, was essentially unknown. The availability of bolometers radically changed the situation, especially because they allowed to *measure dust masses*. The paper you referred to was one of the first surveys of a nearby star-forming region with a bolometer (at the focus of the IRAM 30-m telescope); at that time it was only a single detector, not an array as now, so the survey consisted in observing each interesting source in turn. Given our past observations of the $\rho$ Oph cloud in X-rays and radio, and the links with T Tauri stars, there was no shortage of targets: about 100 sources were observed. Two outflow sources turned out to be particularly interesting: VLA1623 (very strong in the cm range), and IRAS16293 (not seen in the cm range), both strong in the mm continuum but invisible in X-rays. The sources were obviously surrounded by a massive dust envelope that was transparent to radio waves but opaque to X-rays: the emissivity in the mm range indicated an equivalent visual extinction $A_V \sim 100$, in a very small volume (radius $< 2{,}000$ au) since the source was not resolved within the $12''$ beam of the 30-m dish at 1.3 mm. As for the other mm sources, their cold dust emission showed a continuum between the classes of T Tauri stars –with evidence for a sharp transition between Class I (strong mm emission and spatially resolved envelopes) and Class II (IR bright but weaker in mm, unresolved disks). The stronger mm continuum emission of VLA1623 and IRAS16293 clearly suggested younger objects, which we interpreted as the youngest protostar stage –hence the use of the name "Class 0" (previously introduced by Philippe, Derek Ward-Thomson and Mary Barsony) to be added to the Lada classification of young stars.

This new interpretation was not immediately accepted, in particular by Frank Shu and colleagues, who argued that objects like VLA1623 were already evolved, but the issue was finally settled when Philippe demonstrated by higher-resolution, sub-mm bolometer mapping that the proposed Class 0 sources had large stellar-mass envelopes, likely in a state of collapse to form the central object, possibly heated to radio cm temperatures by its own accretion. (The final proof was the detection of Doppler-shifted lines demonstrating the collapse, but that would come much later with the progress of instrumentation.)

The existence of Class 0 sources is now central to test theories of the earliest, collapse stages of star formation.

**Q**: *In 1999 Eric Feigelson and you wrote a highly cited review on high-energy processes in young stellar objects for the Annual Reviews. What are the key new results that have shaped the subject since then?*

**A:** The goal of that review was to establish a milestone in the field of high-energy phenomena in regions of star formation, since the next generation of X-ray satellites (NASA's *Chandra* and ESA's *XMM-Newton*) was about to be launched (1999): the *Einstein/ROSAT/IRAS* generation was gone. The basic phenomena visible in X-rays (coronal emission, flare activity, even hints of non-thermal emission associated with jets, etc.) were firmly established, and the unique power of X-rays to detect "old" pre-main sequence stars (so called "post-T Tauri stars", old Class III stars, etc., i.e., without IR excess and less active) had been demonstrated. However, there were three limitations: (*i*) in spite of the many regions of star formation observed, the number of sources per region was not more than a few dozen, preventing a serious "local" statistical analysis for each region; (*ii*) line spectroscopy was limited to the brightest stars, at low spectral resolution; (*iii*) it was also clear that X-rays alone were not very informative as to the nature of the emitting stars: it was crucial to obtain more information at other wavelengths, in particular concerning circumstellar dust (IR to mm continuum), and also, for the younger stages, outflows and jets (optical, IR and mm lines, etc.). In brief, a "multiwavelength approach" (including, but not limited to, X-rays) was indispensable to understand young, solar-mass stars, their early evolution, and their environment (also higher-mass stars).

In X-rays, *Chandra* and *XMM-Newton* allowed to perform deep and/or extended surveys (mosaics, etc.) of prominent regions of star formation, either at high spatial resolution ($< 0.2$" with *Chandra*) or with a large FOV ($\sim 1^\circ$ with *XMM*). Three such surveys stand out: (*i*) the *Chandra Orion Ultradeep Project* (COUP), led by Eric Feigelson, which consisted in a 1.6 Msec exposure survey of the Orion nebula (as opposed to the usual 30-100 ksec exposure of star-forming regions), which revealed hundreds of young stars, allowing to study the dependence of X-ray emission (luminosity, variability, spectrum, etc.) with other stellar properties (mass, bolometric luminosity, stage of evolution, circumstellar matter, etc.); (*ii*) the *Chandra Carina Complex Project* (CCCP), led by Leisa Townsley, which consisted of a mosaic of 22 *Chandra* fields covering a $2^\circ \times 2^\circ$ area including all its major star clusters, and revealing over 14,000 sources covering a large stellar mass range, and also evidence of widespread diffuse X-ray emission attributed to past supernova remnants and winds from massive stars (also seen later in Orion by *XMM*); (*iii*) the *XMM Extended Survey of Taurus* (XEST), led by Manuel Güdel, which consisted of a mosaic of *XMM* fields covering the whole extent of the Taurus clouds, which revealed not only hundreds of sources, but also subtle effects of circumstellar disks (orientation, accretion, etc.) with specific X-ray spectroscopic signatures.

Now it is a bit difficult to see the future. In my view, the study of star forming regions in X-rays has somehow reached its limits: the present knowledge will be consolidated by more observations, but we don't expect radically new science until the next generation of X-ray satellites is put into space (like ESA's *Athena*), but this is at least 10 years away, which is not necessarily good to attract students...

**Q**: *You have until last year served as the General Secretary of the IAU. How do you see the role of the IAU as astronomy is undergoing rapid changes?*

**A:** As you know, after the Divisions were reformed at the previous IAU General Assembly in Beijng (2012), the last General Assembly held in Honolulu saw the completion of the second phase: the reform of Commissions, and the related renewal of the Division Steering Committees and the Commission Organizing Committees. Out of the 40 Commissions existing before Honolulu, about a third disappeared, a third underwent significant changes -and, with a total number reduced to 35, about 10 Commissions were formed on topics that were not previously represented in the IAU structure: for instance Computational Astrophysics, Astrostatistics and Astroinformatics, and, preceding their recent discovery, Gravitational Wave Astrophysics. So I can say that the IAU is now much more "in sync" with modern astronomy than it used to be. However, strangely enough, my favourite very active fields like star formation or cosmic rays yet do not have a Commission –because nobody from these fields proposed them. Perhaps this will be for the future.

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

**A:** My six years, first as Assistant General Secretary, then as General Secretary, mainly organizing and sheperding the Division and Commission reforms, were of course very exciting but also so time-consuming that I continued my research only from a distance -and thanks to my main collaborators in Grenoble and in Paris... Now I have more time for science, and I'm mostly returning to high-energy astrophysics (supernovae interacting with molecular clouds, some work on X-rays from star-forming regions with Brazilian students and collaborators), preparing a new edition of a book on Supernovae (with my colleague Nicolas Prantzos) that we published after the discovery of SN1987A, almost 30 years ago (!), and... keeping an eye on exoplanets and life in the universe. I hope this will keep me busy for a while !

*Abstracts of recently accepted papers*

## Brown Dwarfs in Young Moving Groups from Pan-STARRS1. I. AB Doradus

**Kimberly M. Aller[1], Michael C. Liu[1], Eugene A. Magnier[1], William M. J. Best[1], Michael C. Kotson[1,2], William S. Burgett[1], Kenneth C. Chambers[1], Klaus W. Hodapp[1], Heather Flewelling[1], Nick Kaiser[1], Nigel Metcalf[3], John L. Tonry[1], Richard J. Wainscoat[1], Christopher Waters[1]**

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Substellar members of young (≲150 Myr) moving groups are valuable benchmarks to empirically define brown dwarf evolution with age and to study the low-mass end of the initial mass function. We have combined Pan-STARRS1 (PS1) proper motions with optical–IR photometry from PS1, 2MASS and WISE to search for substellar members of the AB Dor Moving Group within ≈50 pc and with spectral types of late-M to early-L, corresponding to masses down to ≈30 $M_{\rm Jup}$ at the age of the group (≈125 Myr). Including both photometry and proper motions allows us to better select candidates by excluding field dwarfs whose colors are similar to young AB Dor Moving Group members. Our near-IR spectroscopy has identified six ultracool dwarfs (M6–L4; ≈30–100 $M_{\rm Jup}$) with intermediate surface gravities (INT-G) as candidate members of the AB Dor Moving Group. We find another two candidate members with spectra showing hints of youth but consistent with field gravities. We also find four field brown dwarfs unassociated with the AB Dor Moving Group, three of which have INT-G gravity classification. While signatures of youth are present in the spectra of our ≈125 Myr objects, neither their $J - K$ nor $W1 - W2$ colors are significantly redder than field dwarfs with the same spectral types, unlike younger ultracool dwarfs. We also determined PS1 parallaxes for eight of our candidates and one previously identified AB Dor Moving Group candidate. Although radial velocities (and parallaxes, for some) are still needed to fully assess membership, these new objects provide valuable insight into the spectral characteristics and evolution of young brown dwarfs.

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http://arxiv.org/pdf/1604.04284

## The Gaia-ESO Survey: A lithium-rotation connection at 5 Myr?

**J. Bouvier[1], A. Lanzafame[2], L. Venuti, A. Klutsch, R. Jeffries, A. Frasca, E. Moraux, K. Biazzo, S. Messina, G. Micela, S. Randich, J. Stauffer, A.M. Cody, E. Flaccomio, G. Gilmore, A. Bayo, T. Bensby, A. Bragaglia, C. Carraro, A. Casey, M.T. Costado[3] and F. Damiani, E. Delgado Mena, P. Donati, E. Franciosini, A. Hourihane, S. Koposov, C. Lardo, J. Lewis, L. Magrini, L. Monaco, L. Morbidelli, L. Prisinzano, G. Sacco, L. Sbordone, S.G. Sousa, A. Vallenari, C.C. Worley, S. Zaggia, T. Zwitter[4]**

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The evolution of lithium abundance in cool dwarfs provides a unique probe of nonstandard processes in stellar evolution. We investigate here the lithium content of young low-mass stars in the 5 Myr-old star forming region NGC 2264 and its relationship with rotation. We combine lithium equivalent width measurements, EW(Li), from the Gaia-ESO Survey with the determination of rotational periods from the CSI 2264 survey. We consider only bona fide non accreting cluster members in order to minimize uncertainties on EW(Li). We report the existence of a relationship between lithium content and rotation in NGC 2264 at an age of 5 Myr. The Li-rotation connection is seen over a restricted temperature range, Teff=3800 -4400K, where fast rotators are Li-rich compared to slow ones. This correlation is similar to, albeit of lower amplitude than, the Li-rotation connection previously reported for K dwarfs in the 125 Myr-old Pleiades cluster. We investigate whether the non-standard pre-main sequence models developed so far to explain the Pleiades results, which are based on episodic accretion, pre-main sequence core-envelope decoupling, and/or radius inflation due to enhanced magnetic activity, can account for an early development of the Li-rotation connection. While radius inflation appears to be the most promising possibility, each of these models has issues. We therefore also discuss external causes that might operate during the first few Myr of pre-main sequence evolution, such as planet engulfment and/or steady disk accretion, as possible candidates for the common origin for Li-excess and fast rotation in young low-mass pre-main sequence stars. The emergence of a connection between lithium content and rotation rate at such an early age as 5 Myr suggests a complex link between accretion processes, early angular momentum evolution, and possibly planet formation, which likely impacts early stellar evolution and has yet to be fully deciphered.

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http://arxiv.org/pdf/1604.07580

## *Herschel* detects oxygen in the $\beta$ Pictoris debris disk

**A. Brandeker[1], G. Cataldi[1], G. Olofsson[1], B. Vandenbussche[2], B. Acke[2], M. J. Barlow[3], J. A. D. L. Blommaert[2,4], M. Cohen[5], W. R. F. Dent[6], C. Dominik[7,8], J. Di Francesco[9], M. Fridlund[10], W. K. Gear[11], A. M. Glauser[12], J. S. Greaves[14], P. M. Harvey[15], A. M. Heras[16], M. R. Hogerheijde[17], W. S. Holland[13], R. Huygen[2], R. J. Ivison[18,19], S. J. Leeks[20], T. L. Lim[20], R. Liseau[10], B. C. Matthews[9], E. Pantin[21], G. L. Pilbratt[16], P. Royer[2], B. Sibthorpe[22], C. Waelkens[2] and H. J. Walker[20]**

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The young star $\beta$ Pictoris is well known for its dusty debris disk produced through collisional grinding of planetesimals, kilometre-sized bodies in orbit around the star. In addition to dust, small amounts of gas are also known to orbit the star; this gas is likely the result of vaporisation of violently colliding dust grains. The disk is seen edge on and from previous absorption spectroscopy we know that the gas is very rich in carbon relative to other elements. The oxygen content has been more difficult to assess, however, with early estimates finding very little oxygen in the gas at a C/O ratio that is 20× higher than the cosmic value. A C/O ratio that high is difficult to explain and would have far-reaching consequences for planet formation. Here we report on observations by the far-infrared space telescope *Herschel*, using PACS, of emission lines from ionised carbon and neutral oxygen. The detected emission from $C^+$ is consistent with that previously reported observed by the HIFI instrument on *Herschel*, while the emission from O is hard to explain without assuming a higher density region in the disk, perhaps in the shape of a clump or a dense torus required to sufficiently excite the O atoms. A possible scenario is that the C/O gas is produced by the same process responsible for the CO clump recently observed by ALMA in the disk and that the redistribution of the gas takes longer than previously assumed. A more detailed estimate of the C/O ratio and the mass of O will have to await better constraints on the C/O gas spatial distribution.

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http://arxiv.org/pdf/1604.07418

## H2O masers in a jet-driven bow shock: Episodic ejection from a massive young stellar object

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We report the results of VERA multi-epoch VLBI 22 GHz water maser observations of S255IR-SMA1, a massive young stellar object located in the S255 star forming region. By annual parallax the source distance was measured as $D = 1.78^{+0.12}_{-0.11}$ kpc and the source systemic motion was $(\mu_\alpha \cos\delta, \mu_\delta) = (-0.13 \pm 0.20, -0.06 \pm 0.27)$ mas yr$^{-1}$. Masers appear to trace a U-shaped bow shock whose morphology and proper motions are well reproduced by a jet-driven outflow model with a jet radius of about 6 AU. The maser data, in the context of other works in the literature, reveal ejections from S255IR-SMA1 to be episodic, operating on timescales of $\sim 1000$ years.

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## Pebble Accretion and the Diversity of Planetary Systems

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I examine the standard model of planet formation, including pebble accretion, using numerical simulations. Planetary embryos large enough to become giant planets do not form beyond the ice line within a typical disk lifetime unless icy pebbles stick at higher speeds than in experiments using rocky pebbles. Systems like the Solar System (small inner planets, giant outer planets) can form if (i) icy pebbles are stickier than rocky pebbles, and (ii) the planetesimal formation efficiency increases with pebble size, which prevents the formation of massive terrestrial planets. Growth beyond the ice line is dominated by pebble accretion. Most growth occurs early, when the surface density of pebbles is high due to inward drift of pebbles from the outer disk. Growth is much slower after the outer disk is depleted. The outcome is sensitive to the disk radius and turbulence level, which control the lifetime and maximum size of pebbles. The outcome is sensitive to the size of the largest planetesimals since there is a threshold mass for the onset of pebble accretion. The planetesimal formation rate is unimportant provided that some large planetesimals form while pebbles remain abundant. Two outcomes are seen, depending on whether pebble accretion begins while pebbles are still abundant. Either (i) multiple gas giant planets form beyond the ice line, small planets form close to the star, and a Kuiper-belt-like disk of bodies is scattered outwards by the giant planets; or (ii) no giants form and bodies remain Earth-mass or smaller.

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## An ALMA Search for Substructure, Fragmentation, and Hidden Protostars in Starless Cores in Chamaeleon I

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We present an Atacama Large Millimeter/submillimeter Array (ALMA) 106 GHz (Band 3) continuum survey of the complete population of dense cores in the Chamaeleon I molecular cloud. We detect a total of 24 continuum sources in 19 different target fields. All previously known Class 0 and Class I protostars in Chamaeleon I are detected, whereas all of the 56 starless cores in our sample are undetected. We show that the *Spitzer+Herschel* census of protostars in Chamaeleon I is complete, with the rate at which protostellar cores have been misclassified as starless cores calculated as <1/56, or < 2%. We use synthetic observations to show that starless cores collapsing following the turbulent fragmentation scenario are detectable by our ALMA observations when their central densities exceed $\sim10^8$ cm$^{-3}$, with the exact density dependent on the viewing geometry. Bonnor-Ebert spheres, on the other hand, remain undetected to central densities at least as high as $10^{10}$ cm$^{-3}$. Our starless core non-detections are used to infer that either the star formation rate is declining in Chamaeleon I and most of the starless cores are not collapsing, matching the findings of previous studies, or that the evolution of starless cores are more accurately described by models that develop less substructure than predicted by the turbulent fragmentation scenario, such as Bonnor-Ebert spheres. We outline future work necessary to distinguish between these two possibilities.

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## Protoplanetary Disks in the Orion OMC1 Region Imaged with ALMA

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We present ALMA observations of the Orion Nebula that cover the OMC1 outflow region. Our focus in this paper is on compact emission from protoplanetary disks. We mosaicked a field containing ∼600 near-IR-identified young stars, around which we can search for sub-mm emission tracing dusty disks. Approximately 100 sources are known proplyds identified with HST. We detect continuum emission at 1 mm wavelengths towards ∼20% of the proplyd sample, and ∼8% of the larger sample of near-IR objects. The noise in our maps allows $4\sigma$ detection of objects brighter than ∼1.5 mJy, corresponding to protoplanetary disk masses larger than 1.5 $M_J$ (using standard assumptions about dust opacities and gas-to-dust ratios). None of these disks are detected in contemporaneous CO (2–1) or $C^{18}O$ (2–1) observations, suggesting that the gas-to-dust ratios may be substantially smaller than the canonical value of 100.

Furthermore, since dust grains may already be sequestered in large bodies in ONC disks, the inferred masses of disk solids may be underestimated. Our results suggest that the distribution of disk masses in this region is compatible with the detection rate of massive planets around M dwarfs, which are the dominant stellar constituent in the ONC.

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## Search for associations containing young stars (SACY) VII. New stellar and substellar candidate members in the young associations

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The young associations offer us one of the best opportunities to study the properties of young stellar and substellar objects and to directly image planets thanks to their proximity (<200 pc) and age (≈5-150 Myr). However, many previous works have been limited to identifying the brighter, more active members (≈1 $M_\odot$) owing to photometric survey sensitivities limiting the detections of lower mass objects. We search the field of view of 542 previously identified members of the young associations to identify wide or extremely wide (1000-100,000 au in physical separation) companions. We combined 2MASS near-infrared photometry ($J$, $H$, $K$) with proper motion values (from UCAC4, PPMXL, NOMAD) to identify companions in the field of view of known members. We collated further photometry and spectroscopy from the literature and conducted our own high-resolution spectroscopic observations for a subsample of candidate members. This complementary information allowed us to assess the efficiency of our method.We identified 84 targets (45: 0.2-1.3 $M_\odot$, 17: 0.08-0.2 $M_\odot$, 22: <0.08 $M_\odot$) in our analysis, ten of which have been identified from spectroscopic analysis in previous young association works. For 33 of these 84, we were able to further assess their membership using a variety of properties (X-ray emission, UV excess, $H_\alpha$, lithium and K I equivalent widths, radial velocities, and CaH indices). We derive a success rate of 76–88% for this technique based on the consistency of these properties. Once confirmed, the targets identified in this work would significantly improve our knowledge of the lower mass end of the young associations. Additionally, these targets would make an ideal new sample for the identification and study of planets around nearby young stars. Given the predicted substellar mass of the majority of these new candidate members and their proximity, high-contrast imaging techniques would facilitate the search for new low-mass planets.

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## The crucial role of higher-order multiplicity in wide binary formation: A case study using the $\beta$-Pictoris moving group

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The "in-situ" formation of very wide binaries is hard to explain as their physical separations are beyond the typical size of a collapsing cloud core (≈5000-10,000 au). Here we investigate the formation process of such systems. We compute population statistics such as the multiplicity fraction ( $MF$ ), companion-star fraction ( $CSF$ ) and physical separation distribution of companions in the $\beta$-Pictoris moving group (BPMG). We compare previous multiplicity studies in younger and older regions and show that the dynamic evolution of a young population with a high degree of primordial multiplicity can lead to a processed separation distribution, similar to the field population. The evolution of outer components is attributed to the dynamical unfolding of higher-order (triple) systems; a natural consequence of which is the formation of wide binaries. We find a strong preference for wide systems to contain three or more components (>1000 au: 11 / 14, 10,000 au: 6 / 7). We argue that the majority of wide binaries identified in young moving groups are primordial. Under the assumption that stellar populations, within our galaxy, have statistically similar primordial multiplicity, we can infer that the paucity of wide binaries in the field is the result of dynamical evolution.

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## Radiation hydrodynamical models of the inner rim in protoplanetary disks

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Many stars host planets orbiting within a few astronomical units (AU). The occurrence rate and distributions of masses and orbits vary greatly with the host star's mass. These close planets' origins are a mystery that motivates investigating protoplanetary disks' central regions. A key factor governing the conditions near the star is the silicate sublimation front, which largely determines where the starlight is absorbed, and which is often called the inner rim. We present the first radiation hydrodynamical modeling of the sublimation front in the disks around the young intermediate-mass stars called Herbig Ae stars. The models are axisymmetric, and include starlight heating, silicate grains sublimating and condensing to equilibrium at the local, time-dependent temperature and density, and accretion stresses parametrizing the results of MHD magneto-rotational turbulence models. The results compare well with radiation hydrostatic solutions, and prove to be dynamically stable. Passing the model disks into Monte Carlo radiative transfer calculations, we show that the models satisfy observational constraints on the inner rims's location. A small optically-thin halo of hot dust naturally arises between the inner rim and the star. The inner rim has a substantial radial extent, corresponding to several disk scale heights. While the front's overall position varies with the stellar luminosity, its radial extent depends on the mass accretion rate. A pressure maximum develops near the location of thermal ionization at temperatures about 1000 K. The pressure maximum is capable of halting solid pebbles' radial drift and concentrating them in a zone where temperatures are sufficiently high for annealing to form crystalline silicates.

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## Detailed investigation of the emission structures in the vicinity of LkH$\alpha$ 198

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The results of the study of collimated jets near the star LkH$\alpha$ 198 are presented. The observations were performed with multi-pupil spectrograph VAGR, mounted on 2.6m telescope of BAO. The morphology and kinematics of emission structures in the vicinity of LkH$\alpha$ 198 including HH 161, were studied. The map of electron densities was obtained as well. In addition to HH 161, our data revealed an arcuate emission structure with the LkH$\alpha$ 198 in the apex. It directly points to the presence of the cavity in dark cloud, blown by directed outflow. Moreover, a weak "tail" of HH 161, extended in the direction of the central star, was found. The comparison of these results with the observations in radio range allows us to conclude that the possible source of HH 161 is a binary system LkH$\alpha$ 198.

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## L1599B: Cloud Envelope and C+ Emission in a Region of Moderately Enhanced Radiation Field

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We study the effects of an asymmetric radiation field on the properties of a molecular cloud envelope. We employ observations of carbon monoxide ($^{12}$CO and $^{13}$CO), atomic carbon, ionized carbon, and atomic hydrogen to analyze the chemical and physical properties of the core and envelope of L1599B, a molecular cloud forming a portion of the ring at $\simeq$ 27 pc from the star $\lambda$ Ori. The O III star provides an asymmetric radiation field that produces a moderate enhancement of the external radiation field. Observations of the [C II] fine structure line with the GREAT instrument on SOFIA indicate a significant enhanced emission on the side of the cloud facing the star, while the [C I], $^{12}$CO and $^{13}$CO J = 1-0 and 2-1, and $^{12}$CO J = 3-2 data from the PMO and APEX telescopes suggest a relatively typical cloud interior. The atomic, ionic, and molecular line centroid velocities track each other very closely, and indicate that the cloud may be undergoing differential radial motion. The HI data from the Arecibo GALFA survey and the SOFIA/GREAT [C II] data do not suggest any systematic motion of the halo gas, relative to the dense central portion of the cloud traced by $^{12}$CO and $^{13}$CO.

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## The CDF Archive: Herschel PACS and SPIRE Spectroscopic Data Pipeline and Products for Protostars and Young Stellar Objects

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We present the COPS-DIGIT-FOOSH (CDF) *Herschel* spectroscopy data product archive, and related ancillary data products, along with data fidelity assessments, and a user-created archive in collaboration with the Herschel-PACS and SPIRE ICC groups. Our products include datacubes, contour maps, automated line fitting results, and best 1-D spectra products for all protostellar and disk sources observed with PACS in RangeScan mode for two observing programs: the DIGIT Open Time Key Program (KPOT_nevans_1 and SDP_nevans_1; PI: N. Evans), and the FOOSH Open Time Program (OT1_jgreen02_2; PI: J. Green). In addition, we provide our best SPIRE-FTS spectroscopic products for the COPS Open Time Program (OT2_jgreen02_6; PI: J. Green) and FOOSH sources. We include details of data processing, descriptions of output products, and tests of their reliability for user applications. We identify the parts of the dataset to be used with caution. The resulting absolute flux calibration has improved in almost all cases. Compared to previous reductions, the resulting rotational temperatures and numbers of CO molecules have changed substantially in some sources. On average, however, the rotational temperatures have not changed substantially ($< 2\%$), but the number of warm ($T_{\rm rot} \sim 300$ K) CO molecules has increased by about 18%.

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## Photoevaporation and close encounters: how the environment around Cygnus OB2 affects the evolution of protoplanetary disks

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In our Galaxy, star formation occurs in a variety of environments, with a large fraction of stars formed in clusters hosting massive stars. OB stars have an important feedback on the evolution of protoplanetary disks orbiting around nearby young stars and likely on the process of planet formation occurring in them. The nearby massive association Cygnus OB2 is an outstanding laboratory to study this feedback. It is the closest massive association to our Sun, and hosts hundreds of massive stars and thousands of low mass members, both with and without disks. In this paper, we analyze the spatial variation of the disk fraction (i.e. the fraction of cluster members bearing a disk) in Cygnus OB2 and we study its correlation with the local values of Far and Extreme ultraviolet radiation fields and the local stellar surface density. We present definitive evidence that disks are more rapidly dissipated in the regions of the association characterized by intense local UV field and large stellar density. In particular, the FUV radiation dominates disks dissipation timescales in the proximity (i.e. within 0.5 pc) of the O stars. In the rest of the association, EUV photons potentially induce a significant mass loss from the irradiated disks across the entire association, but the efficiency of this process is reduced at increasing distances from the massive stars due to absorption by the intervening intracluster material. We find that disk dissipation due to close stellar encounters is negligible in Cygnus OB2, and likely to have affected 1% or fewer of the stellar population. Disk dissipation is instead dominated by photoevaporation. We also compare our results to what has been found in other young clusters with different massive populations, concluding that massive associations like Cygnus OB2 are potentially hostile to protoplanetary disks, but that the environments where disks can safely evolve in planetary systems are likely quite common in our Galaxy.

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## An extremely high velocity molecular jet surrounded by an ionized cavity in the protostellar source Serpens SMM1

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We report ALMA observations of a one-sided, high-velocity ($\sim 80\,\mathrm{km\,s^{-1}}$) CO($J = 2$ - $1$) jet powered by the intermediate-mass protostellar source Serpens SMM1-a. The highly collimated molecular jet is flanked at the base by a wide-angle cavity; the walls of the cavity can be seen in both 4 cm free-free emission detected by the VLA and 1.3 mm thermal dust emission detected by ALMA. This is the first time that ionization of an outflow cavity has been directly detected via free-free emission in a very young, embedded Class 0 protostellar source that is still powering a molecular jet. The cavity walls are ionized either by UV photons escaping from the accreting protostellar source, or by the precessing molecular jet impacting the walls. These observations suggest that ionized outflow cavities may be common in Class 0 protostellar sources, shedding further light on the radiation, outflow, and jet environments in the youngest, most embedded forming stars.

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## Observations and modelling of CO and [C I] in protoplanetary disks. First detections of [C I] and constraints on the carbon abundance

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*Context:* The gas-solid budget of carbon in protoplanetary disks is related to the composition of the cores and

atmospheres of the planets forming in them. The principal gas-phase carbon carriers CO, C0, and C+ can now be observed regularly in disks.
*Aims:* The gas-phase carbon abundance in disks has thus far not been well characterized observationally. We obtain new constraints on the [C]/[H] ratio in a large sample of disks, and compile an overview of the strength of [C I] and warm CO emission.
*Methods:* We carried out a survey of the CO 6-5 line and the [C I] 1-0 and 2-1 lines towards 37 disks with the APEX telescope, and supplemented it with [C II] data from the literature. The data are interpreted using a grid of models produced with the DALI disk code. We also investigate how well the gas-phase carbon abundance can be determined in light of parameter uncertainties. Results: The CO 6-5 line is detected in 13 out of 33 sources, [C I] 1-0 in 6 out of 12, and [C I] 2-1 in 1 out of 33. With separate deep integrations, the first unambiguous detections of the [C I] 1-0 line in disks are obtained, in TW Hya and HD 100546.
*Conclusions:* Gas-phase carbon abundance reductions of a factor of 5-10 or more can be identified robustly based on CO and [C I] detections, assuming reasonable constraints on other parameters. The atomic carbon detection towards TW Hya confirms a factor of 100 reduction of [C]/[H]gas in that disk, while the data are consistent with an ISM-like carbon abundance for HD 100546. In addition, BP Tau, T Cha, HD 139614, HD 141569, and HD 100453 are either carbon-depleted or gas-poor disks. The low [C I] 2-1 detection rates in the survey mostly reflect insufficient sensitivity for T Tauri disks. The Herbig Ae/Be disks with CO and [C II] upper limits below the models are debris-disk-like systems. An increase in sensitivity of roughly order of magnitude compared to our survey is required to obtain useful constraints on the gas-phase [C]/[H] ratio in most of the targeted systems.

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## The *Spitzer* infrared spectrograph survey of protoplanetary disks in Orion A: I. disk properties

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We present our investigation of 319 Class II objects in Orion A observed by *Spitzer*/IRS. We also present the follow-up observation of 120 of these Class II objects in Orion A from IRTF/SpeX. We measure continuum spectral indices, equivalent widths, and integrated fluxes that pertain to disk structure and dust composition from IRS spectra of Class II objects in Orion A. We estimate mass accretion rates using hydrogen recombination lines in the SpeX spectra of our targets. Utilizing these properties, we compare the distributions of the disk and dust properties of Orion A disks to those of Taurus disks with respect to position within Orion A (ONC and L1641) and to the sub-groups by the inferred radial structures, such as transitional disks vs. radially continuous full disks. Our main findings are as follows. (1) Inner disks evolve faster than the outer disks. (2) Mass accretion rate of transitional disks and that of radially continuous full disks are statistically significantly displaced from each other. The median mass accretion rate of radially continuous disks in ONC and L1641 is not very different from that in Taurus. (3) Less grain processing has occurred in the disks in ONC compared to those in Taurus, based on analysis of the shape index of the 10 $\mu$m silicate feature ($F_{11.3}/F_{9.8}$). (4) The 20–31 $\mu$m continuum spectral index tracks the projected distance from the most luminous Trapezium star, $\theta^1$ Ori C. A possible explanation is the effect of UV ablation of the outer part of the disks.

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## Simulating the Formation of Massive Protostars: I. Radiative Feedback and Accretion Disks

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We present radiation hydrodynamic simulations of collapsing protostellar cores with initial masses of 30, 100, and 200 $M_\odot$. We follow their gravitational collapse and the formation of a massive protostar and protostellar accretion disk. We employ a new hybrid radiative feedback method blending raytracing techniques with flux-limited diffusion for a more accurate treatment of the temperature and radiative force. In each case, the disk that forms becomes Toomre-unstable and develops spiral arms. This occurs between 0.35 and 0.55 freefall times and is accompanied by an increase in the accretion rate by a factor of 2-10. Although the disk becomes unstable, no other stars are formed. In the case of our 100 and 200 $M_\odot$ simulation, the star becomes highly super-Eddington and begins to drive bipolar outflow cavities that expand outwards. These radiatively-driven bubbles appear stable, and appear to be channeling gas back onto the protostellar accretion disk. Accretion proceeds strongly through the disk. After 81.4 kyr of evolution, our 30 $M_\odot$ simulation shows a star with a mass of 5.48 $M_\odot$ and a disk of mass 3.3 $M_\odot$, while our 100 $M_\odot$ simulation forms a 28.8 $M_\odot$ mass star with a 15.8 $M_\odot$ disk over the course of 41.6 kyr, and our 200 $M_\odot$ simulation forms a 43.7 $M_\odot$ star with an 18 $M_\odot$ disk in 21.9 kyr. In the absence of magnetic fields or other forms of feedback, the masses of the stars in our simulation do not appear limited by their own luminosities.

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## Discovery of an extremely wide-angle bipolar outflow in AFGL 5142

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Most bipolar outflows are associated with individual young stellar objects and have small opening angles. Here we report the discovery of an extremely wide-angle ($\sim$180°) bipolar outflow ("EWBO") in a cluster forming region AFGL 5142 from low-velocity emission of the HCN (3–2) and HCO$^+$ (3–2) lines. This bipolar outflow is along a north-west to south-east direction with a line-of-sight flow velocity of about 3 km s$^{-1}$ and is spatially connected to the high-velocity jet-like outflows. It seems to be a collection of low-velocity material entrained by the high-velocity outflows due to momentum feedback. The total ejected mass and mass loss rate due to both high velocity jet-like outflows and the "EWBO" are $\sim$24.5 M$_\odot$ and $\sim$1.7$\times$10$^{-3}$ $M_\odot$ yr$^{-1}$, respectively. Global collapse of the clump is revealed by the "blue profile" in the HCO$^+$ (1–0) line. A hierarchical network of filaments was identified in $NH_3$ (1,1) emission. Clear velocity gradients of the order of 10 km s$^{-1}$ pc$^{-1}$ are found along filaments, indicating gas inflow along the filaments. The sum of the accretion rate along filaments and mass infall rate along the line of sight is $\sim$3.1$\times$10$^{-3}$ $M_\odot$ yr$^{-1}$, which exceeds the total mass loss rate, indicating that the central cluster is probably still gaining mass. The central cluster is highly fragmented and 22 condensations are identified in 1.1 mm continuum emission. The fragmentation process seems to be determined by thermal pressure and turbulence. The magnetic field may not play an important role in fragmentation.

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## A new star-forming region in Canis Major

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A new southern star-formation region, located at an estimated distance of $\sim$1.5 kpc in the Lynds 1664 dark cloud in Canis Major, is described. Lynds 1664 contains several compact star clusters, small stellar groups, and young stars associated with reflection nebulae. Narrow-band H$\alpha$ and [SII] images obtained with 4-m CTIO telescope reveal more than 20 new Herbig-Haro objects associated with several protostellar outflows.

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## Matching dust emission structures and magnetic field in high-latitude cloud L1642: comparing Herschel and Planck maps

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The nearby cloud L1642 is one of only two known very high latitude ($|b| > 30$ deg) clouds actively forming stars. It is a rare example of star formation in isolated conditions, and can reveal important details of star formation in general, e.g., of the effect of magnetic fields. We compare *Herschel* dust emission structures and magnetic field orientation revealed by *Planck* polarization maps in L1642. The high-resolution ($\sim 20''$) *Herschel* data reveal a complex structure including a dense, compressed central clump, and low density striations. The *Planck* polarization data (at $10'$ resolution) reveal an ordered magnetic field pervading the cloud and aligned with the surrounding striations. There is a complex interplay between the cloud structure and large scale magnetic field. This suggests that the magnetic field is closely linked to the formation and evolution of the cloud. CO rotational emission confirms that the striations are connected with the main clumps and likely to contain material either falling into or flowing out of the clumps. There is a clear transition from aligned to perpendicular structures approximately at a column density of $N_{\rm H} = 1.6 \times 10^{21}\,{\rm cm}^{-2}$. Comparing the *Herschel* maps with the *Planck* polarization maps shows the close connection between the magnetic field and cloud structure even in the finest details of the cloud.

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## Open clusters in Auriga OB2

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We study the area around the HII region Sh 2-234, including the young open cluster Stock 8, to investigate the extent and definition of the association Aur OB2 and the possible role of triggering in massive cluster formation. We obtained Strömgren and $J$, $H$, $K_S$ photometry for Stock 8 and Strömgren photometry for two other cluster candidates in the area, which we confirm as young open clusters and name Alicante 11 and Alicante 12. We took spectroscopy of 33 early-type stars in the area, including the brightest cluster members. We calculate a common distance of $2.80^{+0.27}_{-0.24}$ kpc for the three open clusters and surrounding association. We derive an age 4–6 Ma for Stock 8, and do not find a significantly different age for the other clusters or the association. The star LS V +34°23, with spectral type O8 II(f), is likely the main source of ionization of Sh 2-234. We observe an important population of pre-main sequence stars, some of them with disks, associated with the B-type members lying on the main-sequence. We interpret the region as an area of recent star formation with some residual and very localized ongoing star formation. We do not find evidence for sequential star formation on a large scale. The classical definition of Aur OB2 has to be reconsidered, because its two main open clusters, Stock 8 and NGC 1893, are not at the same distance. Stock 8 is probably located in the Perseus arm, but other nearby HII regions whose distances also place them in this arm show quite different distances and radial velocities and, therefore, are not connected.

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## Evidence that widespread star formation may be underway in G0.253+016, "The Brick"

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Image cubes of differential column density as a function of dust temperature are constructed for Galactic Centre

molecular cloud G0.253+0.016 ("The Brick") using the recently described PPMAP procedure. The input data consist of continuum images from the *Herschel* Space Telescope in the wavelength range 70–500 $\mu$m, supplemented by previously published interferometric data at 1.3 mm wavelength. While the bulk of the dust in the molecular cloud is consistent with being heated externally by the local interstellar radiation field, our image cube shows the presence, near one edge of the cloud, of a filamentary structure whose temperature profile suggests internal heating. The structure appears as a cool ($\sim$ 14 K) tadpole-like feature, $\sim$ 6 pc in length, in which is embedded a thin spine of much hotter ($\sim$ 40–50 K) material. We interpret these findings in terms of a cool filament whose hot central region is undergoing gravitational collapse and fragmentation to form a line of protostars. If confirmed, this would represent the first evidence of widespread star formation having started within this cloud.

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## Direct detection of precursors of gas giants formed by gravitational instability with the Atacama Large Millimetre/sub-millimetre Array

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Phases of gravitational instability are expected in the early phases of disk evolution, when the disk mass is still a substantial fraction of the mass of the star. Disk fragmentation into sub-stellar objects could occur in the cold exterior part of the disk. Direct detection of massive gaseous clumps on their way to collapse into gas giant planets would offer an unprecedented test of the disk instability model. Here we use state-of-the-art 3D radiation-hydro simulations of disks undergoing fragmentation into massive gas giants, post-processed with the RADMC-3D ray-tracing code to produce dust continuum emission maps. These are then fed into the Common Astronomy Software Applications (CASA) ALMA simulator. The synthetic maps show that both overdense spiral arms and actual clumps at different stages of collapse can be detected with the Atacama Large Millimetre/sub-millimetre Array (ALMA) in the full configuration at the distance of the Ophiuchus star forming region (125 pc). The detection of clumps is particularly effective at shorter wavelengths (690 GHz) combining two resolutions with multi-scale clean. Furthermore, we show that a flux-based estimate of the mass of a protoplanetary clump can be from comparable to a factor of 3 higher than the gravitationally bound clump mass. The estimated mass depends on the assumed opacity, and on the gas temperature, which should be set using the input of radiation-hydro simulations. We conclude that ALMA has the capability to detect "smoking gun" systems that are a signpost of the disk instability model for gas giant planet formation.

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## Calibration of evolutionary diagnostics in high-mass star formation

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The evolutionary classification of massive clumps that are candidate progenitors of high-mass young stars and clusters relies on a variety of independent diagnostics based on observables from the near-infrared to the radio. A promising evolutionary indicator for massive and dense cluster-progenitor clumps is the $L/M$ ratio between the bolometric

luminosity and the mass of the clumps. With the aim of providing a quantitative calibration for this indicator we used SEPIA/APEX to obtain $CH_3C_2H$ (12–11) observations, that is an excellent thermometer molecule probing densities $>10^5$ cm$^{-3}$ , toward 51 dense clumps with $M > 1000\ M_\odot$, and uniformly spanning $-2 < \log(L/M) < 2.3$.
We identify three distinct ranges of $L/M$ that can be associated to three distinct phases of star formation in massive clumps. For $L/M < 1$ no clump is detected in $CH_3C_2H$ , suggesting an inner envelope temperature below 30 K. For $1 < L/M < 10$ we detect 58% of the clumps, with a temperature between 30 and 35 K independently from the exact value of $L/M$; such clumps are building up luminosity due to the formation of stars, but no star is yet able to significantly heat the inner clump regions. For $L/M > 10$ we detect all the clumps, with a gas temperature rising with $\log(L/M)$, marking the appearance of a qualitatively different heating source within the clumps; such values are found towards clumps with UCHII counterparts, suggesting that the quantitative difference in $T$–$L/M$ behaviour above $L/M > 10$ is due to the first appearance of ZAMS stars in the clumps.

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## Do siblings always form and evolve simultaneously? Testing the coevality of multiple protostellar systems through SEDs

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(Abridged) Multiplicity is common in field stars and among protostellar systems. Models suggest two paths of formation: turbulent fragmentation and protostellar disk fragmentation. We attempt to find whether or not the coevality frequency of multiple protostellar systems can help to better understand their formation mechanism. The coevality frequency is determined by constraining the relative evolutionary stages of the components in a multiple system. SEDs for known multiple protostars in Perseus were constructed from literature data. Herschel PACS photometric maps were used to sample the peak of the SED for systems with separations ≥7", a crucial aspect in determining the evolutionary stage of a protostellar system. Inclination effects and the surrounding envelope and outflows were considered to decouple source geometry from evolution. This together with the shape and derived properties from the SED was used to determine each system's coevality as accurately as possible. SED models were used to examine the frequency of non-coevality that is due to geometry. We find a non-coevality frequency of 33 ± 10% from the comparison of SED shapes of resolved multiple systems. Other source parameters suggest a somewhat lower frequency of non-coevality. The frequency of apparent non-coevality that is due to random inclination angle pairings of model SEDs is 17 ± 0.5%. Observations of the outflow of resolved multiple systems do not suggest significant misalignments within multiple systems. Effects of unresolved multiples on the SED shape are also investigated. We find that 1/3 of the multiple protostellar systems sampled here are non-coeval, which is more than expected from random geometric orientations. The other 2/3 are found to be coeval. Higher order multiples show a tendency to be non-coeval. The frequency of non-coevality found here is most likely due to formation and enhanced by dynamical evolution.

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## Detection of a turbulent gas component associated with a starless core with subthermal turbulence in the Orion A cloud

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We report the detection of a wing component in $NH_3$ emission toward the starless core TUKH122 with subthermal turbulence in the Orion A cloud. This $NH_3$ core is suggested to be on the verge of star formation because the turbulence inside the $NH_3$ core is almost completely dissipated, and also because it is surrounded by CCS, which resembles the prestellar core L1544 in Taurus showing infall motions. Observations were carried out with the Nobeyama 45 m telescope at 0.05 km $s^{-1}$ velocity resolution. We find that the $NH_3$ line profile consists of two components. The quiescent main component has a small linewidth of 0.3 km $s^{-1}$ dominated by thermal motions, and the red-shifted wing component has a large linewidth of 1.36 km $s^{-1}$ representing turbulent motions. These components show kinetic temperatures of 11 K and < 30 K, respectively. Furthermore, there is a clear velocity offset between the $NH_3$ quiescent gas ($V_{rmLSR} = 3.7$ km $s^{-1}$) and the turbulent gas ($V_{rmLSR} = 4.4$ km $s^{-1}$). The centroid velocity of the turbulent gas corresponds to that of the surrounding gas traced by the $^{13}$CO ($J = 1-0$) and CS ($J = 2-1$) lines. LVG model calculations for CS and CO show that the turbulent gas has a temperature of $8 - 13$ K and an $H_2$ density of *sim* $10^4$ $cm^{-3}$, suggesting that the temperature of the turbulent component is also *sim* 10 K. The detections of both $NH_3$ quiescent and wing components may indicate a sharp transition from the turbulent parent cloud to the quiescent dense core.

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## Infalling-Rotating Motion and Associated Chemical Change in the Envelope of IRAS 16293–2422 Source A Studied with ALMA

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We have analyzed rotational spectral line emission of OCS, $CH_3OH$, $HCOOCH_3$, and $H_2CS$ observed toward the low-mass Class 0 protostellar source IRAS 16293–2422 Source A at a sub-arcsecond resolution ($\sim 0''.6 \times 0''.5$) with ALMA. Significant chemical differentiation is found at a 50 AU scale. The OCS line is found to well trace the infalling-rotating envelope in this source. On the other hand, the $CH_3OH$ and $HCOOCH_3$ distributions are found to be concentrated around the inner part of the infalling-rotating envelope. With a simple ballistic model of the infalling-rotating envelope, the radius of the centrifugal barrier (a half of the centrifugal radius) and the protostellar mass are evaluated from the OCS data to be from 40 to 60 AU and from 0.5 to 1.0 $M_\odot$, respectively, assuming the inclination angle of the envelope/disk structure to be 60° (90° for the edge-on configuration). Although the protostellar mass is correlated with the inclination angle, the radius of the centrifugal barrier is not. This is the first indication of the centrifugal barrier of the infalling-rotating envelope in a hot corino source. $CH_3OH$ and $HCOOCH_3$ may be liberated from ice mantles due to weak accretion shocks around the centrifugal barrier, and/or due to protostellar heating. The $H_2CS$ emission seems to come from the disk component inside the centrifugal barrier in addition to the envelope component. The centrifugal barrier plays a central role not only in the formation of a rotationally-supported disk but also in the chemical evolution from the envelope to the protoplanetary disk.

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## Deriving the Extinction to Young Stellar Objects using [Fe II] Near-infrared Emission Lines: Prescriptions from GIANO High-resolution Spectra

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The near-infrared emission lines of $Fe^+$ at 1.257, 1.321, and 1.644 $\mu$m share the same upper level; their ratios can then be exploited to derive the extinction to a line emitting region once the relevant spontaneous emission coefficients are known. This is commonly done, normally from low-resolution spectra, in observations of shocked gas from jets driven by Young Stellar Objects. In this paper we review this method, provide the relevant equations, and test it by analyzing high-resolution ($R \sim 50000$) near-infrared spectra of two young stars, namely the Herbig Be star HD 200775 and the Be star V1478 Cyg, which exhibit intense emission lines. The spectra were obtained with the new GIANO echelle spectrograph at the Telescopio Nazionale Galileo. Notably, the high-resolution spectra allowed checking the effects of overlapping telluric absorption lines. A set of various determinations of the Einstein coefficients are compared to show how much the available computations affect extinction derivation. The most recently obtained values are probably good enough to allow reddening determination within 1 visual mag of accuracy. Furthermore, we show that [FeII] line ratios from low-resolution pure emission-line spectra in general are likely to be in error due to the impossibility to properly account for telluric absorption lines. If low-resolution spectra are used for reddening determinations, we advice that the ratio 1.644/1.257, rather than 1.644/1.321, should be used, being less affected by the effects of telluric absorption lines.

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## Rapid Circumstellar Disk Evolution and an Accelerating Star Formation Rate in the Infrared Dark Cloud M17 SWex

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We present a catalog of 840 X-ray sources and first results from a 100 ks Chandra X-ray Observatory imaging study of the filamentary infrared dark cloud G014.225−00.506, which forms the central regions of a larger cloud complex known as the M17 southwest extension (M17 SWex). In addition to the rich population of protostars and young stellar objects with dusty circumstellar disks revealed by Spitzer Space Telescope archival data, we discover a population of X-ray-emitting, intermediate-mass pre–main-sequence stars (IMPS) that lack infrared excess emission from circumstellar disks. We model the infrared spectral energy distributions of this source population to measure its mass function and place new constraints on the inner dust disk destruction timescales for 2–8 $M_\odot$ stars. We also place a lower limit on the star formation rate (SFR) and find that it is quite high ($\dot{M} \geq 0.007\ M_\odot\ \mathrm{yr}^{-1}$), equivalent to several Orion Nebula Clusters in G14.225−0.506 alone, and likely accelerating. The cloud complex has not produced a population of massive, O-type stars commensurate with its SFR. This absence of very massive ($\geq$20 $M_\odot$) stars suggests that either (1) M17 SWex is an example of a distributed mode of star formation that will produce a large OB association dominated by intermediate-mass stars but relatively few massive clusters, or (2) the massive cores are still in the process of accreting sufficient mass to form massive clusters hosting O stars.

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## Massive Quiescent Cores in Orion: VI. The Internal Structures and a Candidate of Transiting Core in NGC 2024 Filament

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We present a multi-wavelength observational study of the NGC 2024 filament using infrared to sub-millimeter continuum and the $NH_3$ $(1,1)$ and $(2,2)$ inversion transitions centered on FIR-3, the most massive core therein. FIR-3 is found to have no significant infrared point sources in the Spitzer/IRAC bands. But the $NH_3$ kinetic temperature map shows a peak value at the core center with $T_{\rm k} = 25$ K which is significantly higher than the surrounding level ($T_{\rm k} = 15$–19 K). Such internal heating signature without an infrared source suggests an ongoing core collapse possibly at a transition stage from first hydrostatic core (FHSC) to protostar. The eight dense cores in the filament have dust temperatures between 17.5 and 22 K. They are much cooler than the hot ridge ($T_{\rm d} = 55$ K) around the central heating star IRS-2b. Comparison with a dust heating model suggests that the filament should have a distance of 3–5 pc from IRS-2b. This value is much larger than the spatial extent of the hot ridge, suggesting that the filament is spatially separated from the hot region along the line of sight.

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## Gaps, rings, and non-axisymmetric structures in protoplanetary disks - Emission from large grains

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Dust grains with sizes around (sub)mm are expected to couple only weakly to the gas motion in regions beyond 10 au of circumstellar disks. In this work, we investigate the influence of the spatial distribution of these grains on the (sub)mm appearance of magnetized protoplanetary disks. We perform non-ideal global 3D magneto-hydrodynamic (MHD) stratified disk simulations, including particles of different sizes ($50\,\mu$m to 1 cm), using a Lagrangian particle solver. Subsequently, we calculate the spatial dust temperature distribution, including the dynamically coupled submicron-sized dust grains, and derive ideal continuum re-emission maps of the disk through radiative transfer simulations. Finally, we investigate the feasibility of observing specific structures in the thermal re-emission maps with the Atacama Large Millimeter/submillimeter Array (ALMA). Depending on the level of turbulence, the radial pressure gradient of the gas, and the grain size, particles settle to the midplane and/or drift radially inward. The pressure bump close to the outer edge of the dead-zone leads to particle-trapping in ring structures. More specifically, vortices in the disk concentrate the dust and create an inhomogeneous distribution of solid material in the azimuthal direction. The large-scale disk perturbations are preserved in the (sub)mm re-emission maps. The observable structures are very similar to those expected from planet-disk interaction. Additionally, the larger dust particles increase the brightness contrast between the gap and ring structures. We find that rings, gaps, and the dust accumulation in the vortex could be traced with ALMA down to a scale of a few astronomical units in circumstellar disks located in nearby star-forming regions. Finally, we present a brief comparison of these structures with those recently found with ALMA in the young circumstellar disks of HL Tau and Oph IRS 48.

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## Globules and Pillars in Cygnus X
## I. Herschel Far-infrared imaging of the CygOB2 environment

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The radiative feedback of massive stars on molecular clouds creates pillars, globules and other features at the interface between the HII region and molecular cloud. We present here Herschel observations between 70 and 500 micron of the immediate environment of the Cygnus OB2 association, performed within the HOBYS program. All structures were detected based on their appearance at 70 micron, and have been classified as pillars, globules, evaporating gasous globules (EGGs), proplyd-like objects, and condensations. From the 70 and 160 micron flux maps, we derive the local FUV field on the PDR surfaces. In parallel, we use a census of the O-stars to estimate the overall FUV-field, that is $10^3$-$10^4$ $G_0$ close to the central OB cluster (within 10 pc) and decreases down to a few tens $G_0$, in a distance of 50 pc. From a SED fit to the four longest Herschel wavelengths, we determine column density and temperature maps and derive masses, volume densities and surface densities for these structures. We find that the morphological classification corresponds to distinct physical properties. Pillars and globules have the longest estimated photoevaporation lifetimes, a few $10^6$ yr, while all other features should survive less than that. These lifetimes are consistent with that found in simulations of turbulent, UV-illuminated clouds. We propose a tentative evolutionary scheme in which pillars can evolve into globules, which in turn then evolve into EGGs, condensations and proplyd-like objects.

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## An extensive numerical survey of the correlation between outflow dynamics and accretion disk magnetization

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We investigate the accretion-ejection process of jets from magnetized accretion disks. We apply a novel approach to the jet-launching problem in order to obtain correlations between the physical properties of the jet and the underlying disk.
We extend and confirm the previous works of Tzeferacos et al. 2009 and Murphy et al. 2010 by scanning a large parameter range for the disk magnetization, $\mu_{\rm D} = 10^{-3.5}...10^{-0.7}$.
We disentangle the disk magnetization at the foot point of the outflow as the main parameter that governs the properties of the outflow. We show how the four jet integrals known from steady-state MHD are correlated to the disk magnetization at the jet foot point. This agrees with the usual findings of the steady-state theory, however, here we obtain these correlations from time-dependent simulations that include the dynamical evolution of the disk in the treatment.
In particular, we obtain robust correlations between the local disk magnetization and (i)the outflow velocity, (ii) the jet mass loading, (iii) jet angular momentum, and (iv) the local mass accretion rate.
Essentially we find that strongly magnetized disks launch more energetic and faster jets, and, due to a larger Alfvén lever arm, these jets extract more angular momentum from the underlying disk. These kind of disk-jet systems have, however, a smaller mass loading parameter and a lower mass ejection-to-accretion ratio.
The jets are launched at the disk surface where the magnetization is $\mu(r,z) \simeq 0.1$.
The magnetization rapidly increases vertically providing the energy reservoir for subsequent jet acceleration. We find indication for a critical disk magnetization $\mu_{\rm D} \simeq 0.01$ that separates the regimes of magnetocentrifugally-driven and magnetic pressure-driven jets.

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## Capture of planetesimals by waning circumplanetary gas disks

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When gas giant protoplanets grow sufficiently massive, circumplanetary disks would form. While solid bodies captured by the circumplanetary disks likely contribute to the growth of the planets and regular satellites around them, some of captured bodies would remain in planet-centered orbits after the dispersal of the disk. We examine capture and subsequent orbital evolution of planetesimals in waning circumplanetary gas disks using three-body orbital integration. We find that some of captured planetesimals can survive in the circumplanetary disk for a long period of time under such weak gas drag. Captured planetesimals have semi-major axes smaller than about one third of the planet's Hill radius. Distributions of their eccentricities and inclinations after disk dispersal depend on the strength of gas drag and the timescale of disk dispersal, and initially strong gas drag and quick disk dispersal facilitates capture and survival of planetesimals. However, in such a case, final orbital eccentricities and inclinations of captured bodies remain rather large. Although our results suggest that some of the present irregular satellites of gas giant planets with small semi-major axes would have been captured by gas drag, other mechanisms are required to fully explain their current orbital characteristics.

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## A Catalog of Low-Mass Star-Forming Cores Observed with SHARC-II at 350 microns

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We present a catalog of low-mass dense cores observed with the SHARC-II instrument at 350 $\mu$m. Our observations have an effective angular resolution of $10''$, approximately 2.5 times higher than observations at the same wavelength obtained with the *Herschel Space Observatory*, albeit with lower sensitivity, especially to extended emission. The catalog includes 81 maps covering a total of 164 detected sources. For each detected source, we tabulate basic source properties including position, peak intensity, flux density in fixed apertures, and radius. We examine the uncertainties in the pointing model applied to all SHARC-II data and conservatively find that the model corrections are good to within $\sim 3''$, approximately 1/3 of the SHARC-II beam. We examine the differences between two array scan modes and find that the instrument calibration, beam size, and beam shape are similar between the two modes. We also show that the same flux densities are measured when sources are observed in the two different modes, indicating that there are no systematic effects introduced into our catalog by utilizing two different scan patterns during the course of taking observations. We find a detection rate of 95% for protostellar cores but only 45% for starless cores, and demonstrate the existence of a SHARC-II detection bias against all but the most massive and compact starless cores. Finally, we discuss the improvements in protostellar classification enabled by these 350 $\mu$m observations.

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## Magellan AO System $z'$, $Y_S$, and $L'$ Observations of the Very Wide 650 AU HD 106906 Planetary System

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We analyze archival data from Bailey and co-workers from the *Magellan* adaptive optics system and present the first 0.9 $\mu$m detection ($z' = 20.3 \pm 0.4$ mag; $\Delta z' = 13.0 \pm 0.4$ mag) of the 11 $M_{\rm Jup}$ circumbinary planet HD 106906AB b, as well as the 1 and 3.8 $\mu$m detections of the debris disk around the binary. The disk has an east-west asymmetry in length and surface brightness, especially at 3.8 $\mu$m where the disk appears to be one-sided. The spectral energy distribution of b, when scaled to the $K_S$-band photometry, is consistent with 1800 K atmospheric models without significant dust reddening, unlike some young, very red, low-mass companions such as CT Cha B and 1RXS 1609 B. Therefore, the suggested circumplanetary disk of Kalas and co-workers might not contain much material, or might be closer to face-on. Finally, we suggest that the widest ($a \gtrsim 100$ AU) low mass ratio ($M_{\rm p}/M_\star \equiv q \lesssim 0.01$) companions may have formed inside protoplanetary disks, but were later scattered by binary/planet interactions. Such a scattering event may have occurred for HD 106906AB b with its central binary star, but definitive proof at this time is elusive.

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## Low-metallicity Young Clusters in the Outer Galaxy. II. Sh 2-208

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We obtained deep near-infrared images of Sh 2-208, one of the lowest-metallicity H II regions in the Galaxy, [O/H] = −0.8 dex. We detected a young cluster in the center of the H II region with a limiting magnitude of $K = 18.0$ mag ($10\sigma$), which corresponds to a mass detection limit of $\sim 0.2\,M_\odot$. This enables the comparison of star-forming properties under low metallicity with those of the solar neighborhood. We identified 89 cluster members. From the fitting of the $K$-band luminosity function (KLF), the age and distance of the cluster are estimated to be ∼0.5 Myr and ∼4 kpc, respectively. The estimated young age is consistent with the detection of strong CO emission in the cluster region and the estimated large extinction of cluster members ($A_V \sim 4$–25 mag). The observed KLF suggests that the underlying initial mass function (IMF) of the low-metallicity cluster is not significantly different from canonical IMFs in the solar neighborhood in terms of both high-mass slope and IMF peak (characteristic mass). Despite the very young age, the disk fraction of the cluster is estimated at only 27±6 %, which is significantly lower than those in the solar metallicity. Those results are similar to Sh 2-207, which is another low-metallicity star-forming region close to Sh 2-208 with a separation of 12 pc, suggesting that their star-forming activities in low-metallicity environments are essentially identical to those in the solar neighborhood, except for the disk dispersal timescale. From large-scale mid-infrared images, we suggest that sequential star formation is taking place in Sh 2-207, Sh 2-208 and the surrounding region, triggered by an expanding bubble with a ∼30 pc radius.

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## The Orion fingers: Near-IR spectral imaging of an explosive outflow

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We present near-IR (1.1–2.4 $\mu$m) position-position-velocity cubes of the 500-year-old Orion BN/KL explosive outflow with spatial resolution $1''$ and spectral resolution 86 km s$^{-1}$. We construct integrated intensity maps free of continuum sources of 15 $H_2$ and [Fe II] lines while preserving kinematic information of individual outflow features. Included in the detected $H_2$ lines are the 1–0 S(1) and 1–0 Q(3) transitions, allowing extinction measurements across the outflow. Additionally, we present dereddened flux ratios for over two dozen outflow features to allow for the characterization of the true excitation conditions of the BN/KL outflow. All ratios show the dominance of shock excitation of the $H_2$ emission, although some features exhibit signs of fluorescent excitation from stellar radiation or J-type shocks. We also detect tracers of the PDR/ionization front north of the Trapezium stars in [O I] and [Fe II] and analyze other observed outflows not associated with the BN/KL outflow.

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## Gas of 96 Planck cold clumps in the second quadrant

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Ninety six Planck cold dust clumps in the second quadrant were mapped with $^{12}$CO (1-0), $^{13}$CO (1-0), and C$^{18}$O (1-0) lines at 13.7 m telescope of Purple Mountain Observatory. $^{12}$CO (1-0) and $^{13}$CO (1-0) emissions were detected for all 96 clumps, while C$^{18}$O (1-0) emissions were detected in 81 of them. 15 clumps have more than one velocity components. In the mapped 115 velocity components, 225 cores were obtained. 23.6% of the cores have non-guassian profiles. We acquired V$_{lsr}$, FWHM, and $T_A$ of lines. Distances, $T_{ex}$, velocity dispersions, $N_{H_2}$, and masses were also derived. Generally, turbulence may dominant the cores because $\sigma_{NT}/\sigma_{Therm}$ >1 in almost all the cores and Larson's relationship is not apparent in our massive cores. Virial parameters are adopted to test the gravitational stability of cores and 51% of the cores are likely collapsing. Core mass function of cores in 0-1 kpc suggests a low core-to-star conversional efficiency (0.62%). Only 14 of 225 cores (6.2%) have associated stellar objects in their centers, the others are starless. The morphologies of clumps are mainly filamentary structures. Seven clumps may be located on an extension of the new spiral arm in the second quadrant while 3 are on the known outer arm.

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*Abstracts of recently accepted major reviews*

## Dust Evolution and the Formation of Planetesimals

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The solid content of circumstellar disks is inherited from the interstellar medium: dust particles of at most a micrometer in size. Protoplanetary disks are the environment where these dust grains need to grow at least 13 orders of magnitude in size. Our understanding of this growth process is far from complete, with different physics seemingly posing obstacles to this growth at various stages. Yet, the ubiquity of planets in our galaxy suggests that planet formation is a robust mechanism. This chapter focuses on the earliest stages of planet formation, the growth of small dust grains towards the gravitationally bound "planetesimals", the building blocks of planets. We will introduce some of the key physics involved in the growth processes and discuss how they are expected to shape the global behavior of the solid content of disks. We will consider possible pathways towards the formation of larger bodies and conclude by reviewing some of the recent observational advances in the field.

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# Debris disks and the search for life in the universe

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Ph.D degree awarded: April 2016

Circumstellar debris disks are the extrasolar analogues of the asteroid belt and the Kuiper belt. These disks consist of comets and leftover planetesimals that produce circumstellar dust through mutual collisions. As an obvious outcome of the planet formation process, debris disks can help us constrain planet formation theories and learn about the history of our own solar system. Structures in the disks such as gaps or warps can hint at the presence of planets. Thus, the study of debris disks is an important branch of exoplanetary science. In this thesis, some aspects of debris disks are considered in detail.

A handful of debris disks show observable amounts of gas besides the dust. One such case is the edge-on debris disk around the young A-type star $\beta$ Pictoris, where the gas is thought to be of secondary origin, i.e. derived from the dust itself. By observing this gas, we can thus learn something about the dust, and therefore about the building blocks of planets. The thesis presents spectrally resolved observations of C II emission from the $\beta$ Pic disk with *Herschel*/HIFI. The line profile is used to constrain the spatial distribution of carbon gas in the disk, which helps understanding the gas producing mechanism. We also analyse C II and O I emission detected with *Herschel*/PACS and find that the oxygen must be located in a relatively dense region, possibly similar to the CO clump seen by ALMA. An upcoming analysis of our ALMA C I observations will give us a clearer picture of the system.

Another famous debris disk is found around the nearby, 440 Myr old A-star Fomalhaut. Its eccentricity and sharp edges suggest shaping by a planet. However, gas-dust interactions may result in a similar morphology without the need to invoke planets. We test this possibility by analysing non-detections of C II and O I emission by *Herschel*/PACS. We find that there is not enough gas present to efficiently sustain gas-dust interactions, implying that the morphology of the Fomalhaut belt is due to a yet unseen planet or alternatively stellar encounters.

One of the biggest challenges in exoplanetary research is to answer the question whether there are inhabited worlds other than the Earth. With the number of known rocky exoplanets in the habitable zone increasing rapidly, we might actually be able to answer this question in the coming decades. Different approaches exist to detect the presence of life remotely, for example by studying exoplanetary atmospheres or by analysing light reflected off the surface of an exoplanet. We study whether biosignatures (for example, certain minerals or microorganisms) ejected into a circumstellar debris disk by an impact event could be detected. We consider an impact similar to the Chicxulub event and model the collisional evolution of the ejected debris. We find that dust from such an event can potentially be detected by current telescopes, but analysis of the debris *composition* has to wait for future, advanced instruments.

http://arxiv.org/pdf/1604.08540

*New Jobs*

## Postdoctoral Research Scientist in Star and Planet Formation

The Kapteyn Astronomical Institute in Groningen, The Netherlands, invites applications for a postdoctoral research scientist. The successful candidate is expected to carry out research on protoplanetary disks. He or she will be required to do code development, but also participate in the analysis and interpretation of observational data (VLT, ALMA) in close collaboration with the groups of Prof. Dr. Carsten Dominik (University of Amsterdam) and Prof. Dr. Rens Waters (University of Amsterdam, SRON). We plan to work on establishing the connection between protoplanetary disks and the resulting planetary system architecture through a combination of observations and models.

The group of Dr. Kamp is strongly involved in research on the structure and evolution of protoplanetary disks linking sophisticated two-dimensional thermo-chemical disk models with new multi-wavelength observational data. The postdoctoral research scientist will encounter a stimulating scientific environment ranging from cosmology, galaxy evolution, star and planet formation and interstellar matter to instrumentation. The institute is co-located with the low-energy division of the Netherlands Institute for Space Research (SRON), the PI institute for the SPICA/SAFARI instrument. The Kapteyn Institute is part of the Netherlands Research School for Astronomy and belongs to the top research institutions in Astronomy worldwide. Thus, there is an exciting range of opportunities to establish new collaborations.

Interested applicants should have a PhD in astrophysics or physics and proven experience in programming. The ability to work in an international team and a good command of the English language are essential. Experience with IR, far-IR and/or submm observations is an asset.

The University of Groningen offers an appointment for two years with the option of extension conditional on satisfactory performance to a third year. The job is fulltime (38h/week) with a maximum salary of 3,400 (salary scale 10.7 Dutch Universities) gross per month, depending on qualifications and work experience. University of Groningen is an equal-opportunity employer.

Interested candidates should send application material, including a curriculum vitae, a brief statement of past research and future plans (max. 3 pages), and arrange for three letters of reference to be sent to Prof. Dr. Inga Kamp, Kapteyn Astronomical Institute, P.O. Box 800, 9700 AV Groningen, The Netherlands (E-mail address: kamp@astro.rug.nl). Selection of candidates will start June 20, 2016, and will continue until the position is filled.

## Postdoc Position in the Star and Planet Formation Group at IPAG

Applications are invited for a postdoctoral position in the star and planet formation group (ODYSSey team) of the Institute of Planetology and Astrophysics of Grenoble (IPAG) to work on the analysis of photometric and astrometric data of young clusters and associations from Gaia (first release expected in 2016) and complementary ground-based studies (DANCe, GES). The project will involve the development of statistical methods to characterize the region properties in 6-dimensional phase space (three position and three velocity dimensions) at various scales, in order to constrain the physical conditions and dynamics of stellar cluster formation.

Applicants must have a PhD in astronomy or astrophysics at the start of the position. Experience in statistical analysis of stellar population and/or in star formation would be desirable. The position is available for a period of 36 months. The starting date is negotiable, but the successful applicant should be in post by 1st December 2016.

The position is part of a European Union funded network "StarFormMapper (via call H2020-COMPET-2015), which aims to understand the formation and evolution of stellar clusters and associations in which massive stars form, by exploiting existing data from Herschel and up-coming data from Gaia. The research network comprises 3 Universities University of Leeds (the leader), Universit Grenoble Alpes, Cardiff University  and a Madrid-based company Quasar Science Resources, S.L. This international partnership will afford the appointee unique opportunities to enlarge his/her network as he/she will work with astronomers and computer scientists from a wide range of backgrounds and skill-sets. The Grenoble node is responsible of the analysis of the Gaia data. The statistical tools will be tested against the outcomes of N-body and hydrodynamical simulations of cluster formation provided by the Cardiff node before being applied to star forming regions. Present-day statistical properties of young cluster members, extending from the highest mass objects all the way down to brown dwarfs (where no extinction is present), will be established and then compared with high spatial resolution data from Herschel and IRAM to look for correlations in the position and velocity phase space between stars and gas. This will allow us to better understand the role of the gas in shaping cluster substructures during the early evolution, from the embedded phase to the gas removal.

IPAG is a world-leading institute in astronomy and astrophysics, especially in the topics of stellar and planetary formation, from the initial phases of the core collapse to the circumstellar disk physics and chemistry and planet formation, but also on exoplanet detection and characterization, and on planetary science. IPAG is also involved on cutting edge instrumental development (e.g. SPHERE, PIONIER, AMBER, E-ELT/MAORY), and takes benefit from the IRAM proximity and the Grenoble University environment. For further details about IPAG see http://ipag.osug.fr/.

Informal enquiries about the position may be addressed to Dr. Estelle Moraux (Estelle.Moraux@univ-grenoble-alpes.fr). Applicants should send their curriculum vitae, a list of publications, and a brief description of research interests to the above address. Letters of reference should also be sent by the application deadline.

Net salary: 25 - 33 kEuros per annum (dependent on experience)

Closing Date: 30/06/2016

## 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.

## Summer School
## "The HR diagram in radio - stellar physics at long wavelengths"
### Sept 26-30, 2016, Arcachon, France

The french Programme National de Physique Stellaire organizes the 2016 Evry Schatzman School entitled: "The HR diagram in radio - stellar physics at long wavelengths". The school program also covers circumstellar radio emission (jets, disks, AGB winds and envelopes), and will introduce the participants to the use of modern ground radio observatories NOEMA, ALMA and SKA.

The School will take place from 26 to 30 September 2016 in the Teich Bird Reserve (on the Atlantic coast next to Arcachon and Bordeaux, France). All lectures will be given in English, at a level geared to Ph.D. students and young researchers.

There are no registration fees. Lodging and meal expenses are 300 euros in total for the School duration. Financial support is available, and can be applied for when you pre-register.

Registration is open up to 31 May 2016, on the dedicated Web site where all scientific and practical information are given. http://ees2016.sciencesconf.org/

Program :

Lectures:
• the HR diagram in radio: observational techniques and emission processes: 2 x 1h30 (Eric Josselin)
• activity, binarity, and magnetism as seen in the radio : 2 x 1h30 (Wouter Vlemmings)
• Solar type stars: chromospheric and coronal radio emission, magnetospheres: 2 x 1h30 (Sven Wedemeyer)
• Star formation and protostars in the radio range:
- Disks : 2h (Anne Dutrey)
- Jets : 2h (Frederic Gueth)
• Winds and mass-loss in the radio range:
- Hot stars : 2h (Jean-Claude Bouret)
- Cold stars : 2h (Sofia Ramstedt)

Seminars and tutorials:
- presentation of ALMA and NOEMA : 1h30 (Sebastien Maret)
- presentation of SKA : 1h30 (Stephane Corbel)
- Preparation and reduction of radio observations : 2 x 2h (Fabrice Herpin & Stephane Guilloteau)

It will possible to present e-posters which will be communicated to participants on an USB key. Posters will be discussed during the school.

Should you have any question, please contact Eric Josselin (eric.josselin(at)umontpellier.fr) or Yveline Lebreton (Yveline.Lebreton(at)obspm.fr).

The SOC (E. Josselin, Y. Lebreton, F. Herpin, S. Cabrit)

## *Summary of Upcoming Meetings*

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

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

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

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

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

**New Directions in Planet Formation**
11 - 15 July 2016 Leiden, The Netherlands
https://www.lorentzcenter.nl/lc/web/2016/799/info.php3?wsid=799&venue=Oort

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

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

**Star Formation in Different Environments**
25 - 29 July 2016, Quy Nhon, Viet Nam
http://sfde16.0x1115.org/

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

**Star Clusters: from Infancy to Teenagehood**
8 - 12 August 2016, Heidelberg, Germany
http://wwwstaff.ari.uni-heidelberg.de/infant_clusters_2016/

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

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

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

**Heating and Cooling Processes in the ISM**
7 -9 September 2016 Cologne, Germany
https://www.astro.uni-koeln.de/hac2016

**Linking Exoplanet and Disk Compositions**
12 - 14 September, 2016 Baltimore, USA
http://www.stsci.edu/~banzatti/images/workshop.pdf

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

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

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

**The ISM-SPP Olympian School of Astrophysics 2016**
3 - 7 October 2016, Mt. Olympus, Greece
http://school2016.olympiancfa.org/

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

**Search for life: from early Earth to exoplanets**
12 - 16 December 2016, Quy Nhon, Vietnam
http://rencontresduvietnam.org/conferences/2016/search-for-life

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