The Star Formation Newsletter

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

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Cover Picture

The Aquila Rift is the dark band in the Milky Way through the constellations of Aquila, Serpens, and eastern Ophiuchus. The image shows the region around Lynds 673 in Aquila, a region with remarkably little star formation activity. The nebulous star is the bright T Tauri star AS 353A, which is a small triple system associated with the Herbig-Haro jet HH 32. This flow is highly inclined to the plane of the sky, so we look down to the source almost along the flow axis; the AS 353 system is likely to be obscured from most other angles.

Image courtesy Adam Block, Mount Lemmon SkyCenter, University of Arizona

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
Q: You got your PhD from Harvard in 1964. Who was your adviser and what was the subject?

A: I worked with Bill Liller (thesis advisor) and with Eugene Avrett. During the latter part of my undergraduate days (Harvard, class of 1962) and throughout my two years in graduate school, I worked to develop the computing apparatus needed to calculate non-grey model atmospheres for early type (Teff > 9000 K) stars along with hydrogen line profiles. Between 1964 and 1967, Gene Avrett, Wolfgang Kalkoffen, and Robert Kurucz collaborated to extend this program to (a) lower temperature (T > 5000 K) stars; (b) include the effects of line blanketing using opacity distribution functions; and (c) include the effects of departures from LTE. In parallel, I worked with Liller to obtain spectral scans (R ∼100) of main sequence O and B stars (working at Agassiz station at Harvard), and with then graduate student David Latham to obtain high resolution spectra using the newly commissioned McMath Solar Telescope at Kitt Peak. With Karen Strom and Robert Kurucz, I developed a program to calculate stellar abundances.

Q: You and your wife Karen have worked as a close team for many years. When did the two of you see the light and start working on young stars?

A: Our interest in observational astronomy fully developed while we spent two semesters at Caltech by invitation from Jesse Greenstein. Apropos YSOs, you would be surprised to know that Cecilia Gaposchkin was the initial inspiration. During my junior year at Harvard, I was fortunate to take a course with her focused on variable stars. I drew as my term assignment the task of demonstrating that the T-Tauri and earlier-type variable stars in NGC 2264 were really PMS cluster members as opposed to more proximate stars located between earth and the cluster/association. This piqued my interest in YSOs (a term, by the way, that Gary Grasdalen and we popularized; we thought that if extragalactic folk could have QSOs we could have YSOs!), and following our move to SUNY Stony Brook in 1968, we began to combine our studies of model atmospheres with the study of YSOs. In particular, we focussed on demonstrating that the PMS late-B and early-A stars in NGC 2264 had surface gravities consistent with their apparent location above the ZAMS, using comparison of observed hydrogen line profiles and model calculations as a tool. We argued that some stars in NGC 2264 were surrounded by ‘circumstellar shells’ (we would now call them infalling envelopes and/or flared disks). While at Stony Brook, I was charged with building an astronomy program, and in setting out the ‘parameters’ for the program, I thought that one focus should be on the newly-developing field of infrared astronomy. As a result, we recruited young faculty and post-doctoral fellows with interests in this area and who built both near- and far-infrared photometers (‘one pixel arrays’ for those too young to remember!). It was with these photometers, as well as those at Kitt Peak that we began studies of the infrared properties of YSOs.

Q: Back in 1972, you and Karen and your collaborators wrote a widely cited paper on Herbig Ae/Be stars. What were your key conclusions?

A: The work on Herbig Ae/Be stars followed naturally from our studies of NGC 2264 in which we made use of surface gravity measurements to locate YSOs, some surrounded by ‘shells’ in the HR diagram. We used optical SEDs and hydrogen line profiles to establish that a subset of Ae/Be stars (those of late-B and early-A types) indeed had surface gravities that placed them on equilibrium radiative tracks. For those objects with no obvious connection to a cluster or association, this was important in establishing that they were truly PMS objects. Our survey of known Ae/Be stars also established their near- and mid-IR properties. Perhaps most intriguing (in retrospect) was our tentative suggestion that it might be possible that objects such as the early-type star W90 in NGC 2264 might be surrounded by disks viewed nearly edge-on. Although Mendoza and others in Mexico had suggested this possibility, our measurements provided quantitative motivation for further testing this hypothesis. Our interest in Ae/Be stars persisted, and culminated in the landmark work by Lynne Hillenbrand, who collaborated with us, Suzan Edwards and others in fleshing out their IR, sub-mm and mm as well as their clustering properties.

Q: Forty years ago, in 1974, came two papers on Herbig-Haro objects, which were at the same time prescient and controversial. What is the story behind those two papers?

A: The tale of HH objects is rather a long one. It started in 1971 when Karen and I (along with our family of 4 children, then ages 5 to 11) spent a sabbatical semester at UC Berkeley. At that time, Gary Grasdalen was a
It is surprising that each of us wasn’t able to see that the HH phenomenon was a manifestation of (a) an outflowing wind and associated shock regions; and (b) in some cases a reflection component, in which the path from YSO to reflection patch had been cleared by a wind which had carved out a cavity. I still cherish the correspondence between Herbig, Haro and Karen and me: correspondence which reflected the passion with which we adhered to our views. Our efforts extended to identifying additional HH object candidates (from examination of the Palomar Sky Survey), searching for their embedded counterparts via IR mapping.

Q: In a later detailed study of the HH 1/2 region, you discovered what is now known as the HH 1 jet.

A: It was inevitable that our attention would sooner or later turn to the iconic HH objects in Orion: HH 1 and 2. VLA observations revealed a continuum source at the midpoint between HH1 and HH2. Deep exposures revealed what appeared to be a narrow, conical reflection nebula surrounding the outflow axis defined by the HH objects (whose proper motions had been measured by Herbig and strongly suggested a highly collimated, bipolar outflow). The polarization pattern pointed to the VLA source as likely associated with object responsible for driving the outflow. By making use of the surface brightness of the reflection nebula at several wavelengths, combined with some plausible assumptions about the scattering properties of the surrounding medium, we were able to infer the luminosity of the source although, at the time, it remained invisible even at IR wavelengths. Our results suggested (not surprisingly) a PMS star (based on its inferred luminosity) which we argued was obscured by an optically thick disk viewed nearly edge on.

Q: During the seventies you and Karen and your collaborators Fred Vrba and Gary Grasdalen performed the first widefield near-infrared surveys of star forming regions such as ρ Ophiuchi, NGC 1333, L1551, and L1630. You discovered many of the best known IR sources such as L1551 IRS5. How did that project get started?

A: As I mentioned above, our interest in mapping star-forming regions began in the early 1970s, when Grasdalen, Luis Carrasco, Karen and I began our pilot near-IR image intensifier imaging. When we arrived at Kitt Peak, we began an effort to enable the 50” to respond to computer commands to execute precise offsets from optically visible stars and to initiate mapping programs. Grasdalen, along with programmers Bill Brown and Jeff Moeller developed the programs (which were the first step toward computer control of all the KPNO telescopes). Fred Vrba joined the team, and his indefatigable efforts led to the initial mapping of multiple star-forming regions. The source names ’IRS 5’ and ’SSV x’ are well known in the literature, so much so that the source of this nomenclature, quite properly at this stage, has faded from memory. As
an aside, we built one of the first control rooms, hastening my evolution from a ‘real’ to ‘armchair’ astronomer. I’m particularly pleased that this work seemed to stimulate a cottage industry in cloud mapping. Thank goodness that our first efforts (which involved stretching out strip chart recordings of hand-driven raster scans!) to map the Ophiuchus complex have been superseded by the power of panoramic detectors on the ground, and of course the ground-breaking work of IRAS and later SIRTF.

Q: After heading the Five College Astronomy Department at the University of Massachusetts at Amherst for 14 years, you moved to Tucson in 1998 to work for NOAO.

A: By the end of 1998, I had been chair of the Five College Astronomy Department for almost 14 years. That is two ‘biblical cycles’: probably one too many! Karen and I were both extremely proud of the star-formation group we helped to build at UMass and the associated 4 Colleges. It was a joy to work with superb colleagues – especially Suzan Edwards – as well as with graduate students Mike Meyer, Lori Allen, Lynne Hillenbrand (and many, many others), and to develop collaborative meetings with the CfA star formation group (Lee Hartmann, Nuria Calvet, John Stauffer, Scott Kenyon, Charlie Lada) and later with Steve Beckwith at Cornell. So it was great for the better part of 15 years. But during that time, one tends to use administrative ‘bullets’, and by the time I left, I had, as it were, ’emptied the chambers.’ It was time to go back to NOAO, where my passion for the concept of a strong national observatory – undiminished from the time I first used the McMath in 1964 – could be channeled constructively. Sidney Wolff was kind enough to give me a new home and a fair amount of rope. Jeremy Mould, her successor, did the same.

Q: After you retired, both you and Karen returned to a lifelong interest in nature photography, especially in the Southwestern USA, and you have used innovative electronic means to publish and share your images.

A: Many may not know it, but our interest in photography extends back to childhood (in both cases). Moreover, we spent a good deal of time developing techniques for quantitative analysis of photographic (and later digital) images in the course of our decade-long parallel careers as extragalactic astronomers (1975-83). In the late 1970s, we each took a few studio and art history courses at the University of Arizona, and became quite embedded in what continues to be a very stimulating community of photographic artists in Tucson. As a consequence of our spending two summers teaching on the Navajo Reservation, we made connections with a number of Native writers, poets and artists, one of which led (through a few steps) to a collaboration with poet Joy Harjo: Secrets from the Center of the World (University of Arizona Press, 1989). It combines Joy’s superb, moving poetry with my images taken on the lands of the Navajo Nation. After nearly 20,000 volumes sold, it continues in print. During the 1980s and early 1990s, we both kept up a vigorous exhibition schedule while carrying out our research first at NOAO and later at UMass. My work as chair and involvement in two major projects at UMass slowed me down a good deal, but when we returned to the southwest, each of us committed to spending more time on our artistic pursuits. I’ve published 4 books of photography (combined with poetry and essays) since 2000, and am working on several projects as we speak. Karen has been devoting her energies to developing interactive e-books which include her very different photography (I tend toward creating simple images with strong emotional content, while she focuses on making visually challenging composites or animated images which challenge one’s perception). Retirement has been good, and my friends tell me that I look younger than I did when I stepped down as Associate Director for Science at NOAO! But then again, they are friends.

Q: In the 1960’s there were not as many female astronomers as today. Were there barriers to Karen’s and your work?

A: When Karen and I arrived in Pasadena, we were able to make use of the 60” and 100” telescopes on Mount Wilson, and later the 200” at Palomar. However, in 1966, it was ‘unusual’ (read for that impossible) for a woman to either observe alone or with a collaborator spouse. Part of the exclusion devolved around accommodations. The other, unstated, was the ‘proper’ role of women. As 24 and 25 year olds, we expressed our ‘concern’ to then director Horace Babcock. When our host, Jesse Greenstein, learned of our interaction with Horace, he told us in a grandfatherly way “I think you’ve distressed Horace.” Our solution to the problem of accommodations was to rent a VW Camper, park it outside the gate at Mt. Wilson! So while not quite breaking the barrier to a woman’s observing ‘on her own’ we at least took a timid step forward. Kitt Peak was initially equally suspicious of Karen’s accompanying me on observing runs, but with not too much prodding, Nick Mayall and Art Hoag did the right thing. Without going into all the details, Karen’s first professorial appointment (and office of her own, for that matter) was made in the mid 1980s at UMass. We did manage to raise 4 children while some of our most productive research was carried out. Karen, in fact, completed the abundance analysis code while recuperating from the birth of our youngest child in 1966! So for those trying to ‘balance’ career and family, it’s possible – but the hours are long and the guilt can be great. But so can the opportunities. Our kids met a ton of really fascinating people from throughout the world, and to this day, remember the passionate evening discussions we held during the 1970s at our home in Tucson. None of them is a sociopath, although one is a conservative!
1 Motivation

Ultraviolet (UV) observations of T Tauri stars (TTSs) grant direct access to the stellar magnetosphere, the base of the outflow, the accretion flow and its mass repository, the accretion disk; all of them are key elements of the gravo-magnetic engine that transforms gravitational energy (stored in the form of gas and dust orbiting in the disk) into mechanical energy (the jet) using the magnetic field as a mediator. This engine controls pre-main-sequence (PMS) evolution by: (1) tapping the mass flow from the disk onto the star and (2) producing exhausts in terms of radiation and outflows that determine the disk evolution and lifetime. The final budget of angular momentum transferred from the disk onto the star is determined by the efficiency of the engine to drive angular momentum to the macro-scales (outflows and jets) and to the micro-scales (turbulence, magnetic reconnection and, finally, to the thermal-radiative output).

The engine physics is poorly constrained from observations because at early phases it is heavily extincted and, later on, can only be efficiently accessed in the UV range (see Fig. 1). UV facilities provide a unique opportunity to study this engine at work and track the evolution of the coupled star-disk system while planets are built up.

In this perspective, I will just briefly outline the amazing wealth of information derived from the most recent UV studies. Reviews in the field have been produced by the Network of Ultraviolet Astronomy (www.nuva.eu) every few years (Gómez de Castro et al. 2006, 2009, Gómez de Castro & Lamzin 2011, Herczeg 2013). I direct the interested reader to them for more details.

2 Learning about the engine from UV data

The first evidence about the strength of the UV radiation from the engine came from the so-called flux-flux relations, a classical diagnosis tool to study energy transport in the atmosphere of cool stars. Flux-flux relations measure the relative energy budgets in high ionization species (C IV, N V, Si IV) compared with that in low ionization species (Mg II, C II, Si II). In cool stars, these relations are used to study the connection between the chromosphere (traced by neutral or singly ionized species), the transition region (traced by highly ionized species and the He II line at 1640 Å) and the base of the corona.

TTSs display excess radiation in all the UV tracers compared to their main sequence analogues. They also display a unique characteristic, the excess radiation is larger in low ionization than high ionization species. Both characteristics relate to the large extent of stellar magnetospheres in TTSs; notice that the temperature of TTSs magnetospheres is about several thousand Kelvin. These properties seem to extend to the brown dwarf limit (Herczeg & Hillenbrand 2008, France et al. 2010, Gómez de Castro & Marcos-Arenal 2012).

There is a widely reported correlation between the strength of the C IV, N V, Mg II, C II and O I lines and the accretion rate, or mass load, onto the magnetosphere (Ingleby et al. 2011a, Yang et al. 2012, Gómez de Castro & Marcos-Arenal 2012, Ardila et al. 2013, Gómez de Castro 2013). In fact, accurate accretion rates are determined from the UV continuum excess produced by the warm matter in the accretion flow (Ingleby et al. 2011a, 2013).

UV excess is also accompanied by a broadening of the UV line profiles; heavy accretors display very broad profiles and the broadening decreases as the stars approach the main sequence (Ardila et al. 2013, Gómez de Castro 2013). As the outer edge of the magnetosphere is attached to the inner disk border and is forced to rotate at Keplerian speeds, this connection suggests a shrinking contribution of the stellar magnetosphere to the line flux as the accretion rate decreases and the magnetospheric radius increases. Though some evidence has been found in this sense (Gómez de Castro & Marcos-Arenal 2012), the sample is too tiny to be conclusive.

Important clues on the magnetospheric geometry and the characteristics of accretion shocks come also in the UV. Back in the 90’s, Simon et al. ran the first UV monitor-
ing campaign of a TTS, BP Tau, with the 40 cm primary International Ultraviolet Explorer (IUE) space telescope. Only two further UV monitoring programs were run and they showed the same trend: the UV flux (lines and continuum) was found to be rotationally modulated and correlated with the optical veiling (see also Gómez de Castro & Fernández, 1996; Gómez de Castro & Franqueira, 1997). The consensus is that matter infall is channelled onto the stellar surface by the magnetic field producing a shock, the accretion shock, at the point of impact where the kinetic energy of the flow is damped into heating reaching temperatures up to $10^6$ K. Important results from these campaigns were that [1] the rotational modulation only affects to roughly 50% of the UV flux excess and [2] there is an excess of warm plasma (singly ionized species) radiation compared to high ionization tracers also in the spot. Already in the first models of the accretion shock structure (Lamzin 1998, Calvet & Gullbring 1998), it was predicted that the X-ray radiation from the shock front is readily absorbed by the infalling gas producing UV radiation. Unfortunately, the UV line fluxes cannot be used solely as a clean tracer of accretion. High resolution spectroscopy is crucial to separate the coupled components contributing to the line flux: accretion shocks, extended magnetospheric emission (as inferred from the monitoring campaigns), the outflows or the very same stellar atmosphere submitted to the stress of a forced magnetosphere (Gómez de Castro & Marcos-Arenal 2012). High resolution spectroscopy, aided by the variability of the sources can assist in solving this observational degeneracy (see Fig.2).

2.1 Close binaries as a laboratory for magnetospheric studies

PMS spectroscopic binaries display similar UV excesses as their single counterparts do. In these systems, there is a large circumbinary disk (Mathieu et al. 2007), as well as transient circumstellar disks around each component, where the infalling material is stored in parking orbit while angular momentum excess is released. This permits to study directly the physics of the engine and time it with accretion outbursts.

AK Sco stands out among the PMS binaries by the similar mass of the two components (two F5 stars) and its orbital properties; the orbit is very eccentric ($e = 0.47$) and the stars get as close as 11.3 stellar radii at periastron passage (Alencar et al. 2003). Numerical simulations of the evolution of the system are shown in Fig. 3 (Gómez de Castro et al. 2013a). The elliptical orbit results in an interesting phenomenon: when the system approaches periastron, the outer boundaries of the circumstellar disks (and the accretion streams passing by) get close enough to each other to effectively lose the angular momentum, leading to an increase of the accretion rate by a factor of 2-3. A tangential discontinuity is produced at the point where the primary and secondary accretion flows get in contact because, at the interface between them, the matter orbiting around the primary moves in the opposite direction to that of the matter orbiting the secondary. Collisional heating, development of instabilities (like Rayleigh-Taylor instability on the interface) and shock wave formation will efficiently remove the angular momentum and, henceforth, lead to an accretion outburst. As a result, accretion outbursts can
be properly timed and its magnetospheric impact studied.

In a monitoring campaign run with the XMM-Newton telescope, a 1.3mHz ultra low frequency oscillation was detected precisely at periastron passage. The oscillation was detected in the UV light curve, with the Optical Monitor, but unfortunately, the S/N in the X-ray range was too low to detect a high energy counterpart (see Gómez de Castro et al. 2013a, for details). This oscillation lasted 7 ks and had an amplitude equivalent to 6% the average UV luminosity of the AK Sco magnetosphere. The detailed physics driving it is not yet constrained by the observations. An ongoing monitoring program with HST will provide the data to study in detail the process.
3 The mass repository: gas content of the inner disk from UV data

In 2002, Herczeg et al. published the full spectrum of TW Hya in the 1150 Å - 1700 Å spectral range. The spectrum was obtained with the Hubble Space Telescope (HST) and the Space Telescope Imaging Spectrograph (STIS) and displayed an overwhelming richness: 146 Lyman-band H₂ lines. From these observations, Herczeg et al (2004, 2006) estimated a column density of the warm disk $N_{H_2} = 3.2 \times 10^{18}$ cm$^{-2}$, a temperature of $T=2500$ K, and a filling factor of H₂, as seen from the source of the Ly$\alpha$ emission, of $0.25 \pm 0.08$.

The sensitivity of the Cosmic Origins Spectrograph (COS) permitted to extend this study down to column densities $< 10^{-6}$ g cm$^{-2}$. The HST/COS based survey consisted of 34 TTSs including 7 stars hosting weak transitional disks (CS Cha, DM Tau, GM Aur, UX Tau, LkCa 15, HD135344B and TW Hya) and 7 weak lined TTSs (WTTSs). Fluorescent H₂ emission was detected in all the accreting sources (Ingleby et al. 2011b, France et al. 2012a,b). Some sources show evidence of molecular outflows but many profiles can be modelled by a single Gaussian emission line. For these disk-dominated targets, the H₂ emission seems to originate within 3 AU of the parent star.

The detection of H₂ emission from transitional disks has indicated that the inner molecular disk can persist to ages $\sim 10$ Myr in Classical TTSs (Salyk et al. 2009; Ingleby et al. 2011b; France et al. 2012b) significantly higher than the 2-4 Myr timescale for dust disk clearing (Hernández et al. 2007).

In addition to H₂, the CO rovibrational absorption/emission bands have been detected in several TTSs (France et al. 2011; McJunkin et al. 2013). The analysis indicates that the lines are formed in the atmosphere of the inner disk or possibly a slow disk wind or photoevaporative flow.

4 The outflow in the UV

The power of the UV range to study the TTS outflows resides in three basic characteristics:

- the resolution of an optical system increases as $1/\lambda$ thus, the highest resolution is achieved in the UV. For this reason, evidence of rotation at the base of the jet has been sought by observing the Mg II emission at 2800 Å in some protostellar jets (i.e. Coffey et al. 2008, 2012). Research on jet clumpiness and structure would significantly benefit from using UV imagers.

- Lyman $\alpha$ is the strongest line to search for warm diffuse gas in the Universe. Microjets have been detected in this manner around Herbig stars which are not significantly extincted (i.e. Devine et al. 2000).

- the UV grants access to optically thin, semiforbidden lines, being formed at temperatures between $10,000-30,000$ K over a wide range of electron densities: $10^3 - 10^{12}$ cm$^{-3}$ (Gómez de Castro & Verdugo 2001). They permit to explore by spectroscopic means the base of the jet. An important result obtained by comparing with numerical models is that winds being launched from the interface between the star and the Keplerian disk can produce very broad profiles depending on the magnetization of the disk and the strength of the stellar field (see Fig.5).

Figure 4: Evolution of the molecular gas content with age in TTSs (courtesy Kevin France).

5 A final remark

In this brief essay, I have outlined the information contained in the UV radiation field about the physics of the accretion engine, but this radiation actively controls the disk evolution (Alexander et al. 2006, Gorti & Hollenbach 2009). It drives the photo-evaporation of the gas disk setting the final architecture of the giant planets in the system and beginning the epoch of rocky planet formation (Schindhelm et al., 2011, Fogel et al. 2011). It also drives the disk chemistry and chemical evolution (see i.e. van Zadelhoff et al. 2003).

Unfortunately, little is known about the FUV radiation from solar-system precursors. The measurements carried out from X-ray to softer UV bands indicate that the FUV
Figure 5: Dispersion versus centroid for the Si III] line profile. Black triangles represent measurements (the two measurements of RY Tau are connected). Theoretical predictions are color coded by strength of the stellar magnetic field and the characteristics of the disk magnetic field. Note that the profile broadening ($\sigma$) depends mainly on the strength of the stellar magnetic field (see Gómez de Castro & von Rekowsky, 2011 for details).

Flux varies significantly during the pre-main sequence evolution. Protostellar disks are shielded from the energetic stellar radiation during the early phases (<1Myr), but as they evolve into young planetary disks, the FUV and extreme UV (EUV) radiation from the very active young Suns irradiates them heavily. Around the Sun, within a modest radius of 500 pc, there are thousands of young solar-like stars of all masses and in all the phases of PMS evolution. The observation of these sources with high sensitivity mid-resolution spectroscopy would provide a unique perspective on atmospheres, magnetospheres and coronal evolution, as well as on their impact on planetary formation and evolution.

The access to the UV range is currently granted by the NASA led HST mission and it will be granted by the ROSCOSMOS led WSO-UV (www.wso-uv.org) mission in the post-Hubble era.

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Circumstellar Disks Around Binary Stars in Taurus

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We have conducted a survey of 17 wide (> 100 AU) young binary systems in Taurus with the Atacama Large Millimeter Array (ALMA) at two wavelengths. The observations were designed to measure the masses of circumstellar disks in these systems as an aid to understanding the role of multiplicity in star and planet formation. The ALMA observations had sufficient resolution to localize emission within the binary system. Disk emission was detected around all primaries and ten secondaries, with disk masses as low as 10⁻⁴ M☉. We compare the properties of our sample to the population of known disks in Taurus and find that the disks from this binary sample match the scaling between stellar mass and millimeter flux of Fₘ₉ᵉ ∝ M¹.⁵⁻².⁰ to within the scatter found in previous studies. We also compare the properties of the primaries to those of the secondaries and find that the secondary/primary stellar and disk mass ratios are not correlated; in three systems, the circumsecondary disk is more massive than the circumprimary disk, counter to some theoretical predictions.

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An Observational Study of the Temperature and Surface Density Structures of a Typical Full Disk around MWC 480

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This paper presents observations of a protoplanetary disk around a Herbig Ae star MWC 480 in ¹²CO (J=1–0), ¹²CO (J=3–2), ¹³CO (J=1–0), and C¹⁸O (J=1–0) emission lines. Double-peaked emission profiles originating from the rotating circumstellar disk were detected in all of the lines. The vertical temperature and radial surface density structures of the outer region of the disk were derived by applying the similarity solution in the standard accretion disk model. Taking advantage of difference in height of the photosphere among the CO lines, the temperature in the uppermost ¹²CO (J=3–2) emitting layer is shown to be about 3 times higher than that of any other CO emitting region, suggesting that there are at least two distinct temperature regions.

Our modeling succeeds in describing all of the observational results obtained in the four CO lines, particularly different emission extents at different frequencies, by a single set of the parameters for a disk model. Since the similarity solution model could be the most suitable for the radial surface density structure, it is likely that the disk around MWC 480 evolves by transferring angular momentum outward via viscous diffusion. Although further quantitative studies are required in identifying what disk model is the best for describing physical disk structures, our results suggest the potential advantage of the similarity solution model, indicating that disks around Herbig Ae/Be stars likely have diffused gas in the outer regions and the disk surface density exponentially decreases with increasing radial distance.

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Carbon-rich planet formation in a solar composition disk
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The C–to–O ratio is a crucial determinant of the chemical properties of planets. The recent observation of WASP 12b, a giant planet with a C/O value larger than that estimated for its host star, poses a conundrum for understanding the origin of this elemental ratio in any given planetary system. In this paper, we propose a mechanism for enhancing the value of C/O in the disk through the transport and distribution of volatiles. We construct a model that computes the abundances of major C and O bearing volatiles under the influence of gas drag, sublimation, vapor diffusion, condensation and coagulation in a multi–iceline 1+1D protoplanetary disk. We find a gradual depletion in water and carbon monoxide vapors inside the water’s iceline with carbon monoxide depleting slower than water. This effect increases the gaseous C/O and decreases the C/H ratio in this region to values similar to those found in WASP 12b’s day side atmosphere. Giant planets whose envelopes were accreted inside the water’s iceline should then display C/O values larger than those of their parent stars, making them members of the class of so-called “carbon-rich planets”. Accepted by A&A

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An Anomalous Extinction Law in the Cep OB3b Young Cluster: Evidence for dust processing during gas dispersal
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We determine the extinction law through Cep OB3b, a young cluster of 3000 stars undergoing gas dispersal. The extinction is measured toward 76 background K giants identified with MMT/Hectospec spectra. Color excess ratios were determined toward each of the giants using \( V \) and \( R \) photometry from the literature, \( g, r, i \) and \( z \) photometry from SDSS and \( J, H, \) and \( K_s \) photometry from 2MASS. These color excess ratios were the used to construct the extinction law through the dusty material associated with Cep OB3b. The extinction law through Cep OB3b is intermediate between the \( R_V = 3.1 \) and \( R_V = 5 \) laws commonly used for the diffuse atomic ISM and dense molecular clouds, respectively. The dependence of the extinction law on line-of-sight AV is investigated and we find the extinction law becomes shallower for regions with \( A_V > 2.5 \) magnitudes. We speculate that the intermediate dust law results from dust processing during the dispersal of the molecular cloud by the cluster. Accepted by ApJ

http://arxiv.org/pdf/1402.1514

[OI] disk emission in the Taurus star forming region
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The structure of protoplanetary disks is thought to be linked to the temperature and chemistry of their dust and gas. Whether the disk is flat or flaring depends on the amount of radiation that it absorbs at a given radius, and on the efficiency with which this is converted into thermal energy. The understanding of these heating and cooling processes is crucial to provide a reliable disk structure for the interpretation of dust continuum emission and gas line fluxes. Especially in the upper layers of the disk, where gas and dust are thermally decoupled, the infrared line emission is strictly related to the gas heating/cooling processes. We aim to study the thermal properties of the disk in the oxygen line emission region, and to investigate the relative importance of X-ray (1–120 Å) and far-UV radiation (FUV, 912–2070 Å) for the heating balance there. We use [OI] 63 µm line fluxes observed in a sample of protoplanetary disks of the Taurus/Auriga star forming region and compare it to the model predictions presented in our previous work. The data were obtained with the PACS instrument on board the Herschel Space Observatory as part of the Herschel Open Time Key Program GASPS (GAS in Protoplanetary diskS), published in Howard et al. (2013). Our theoretical grid of disk models can reproduce the [OI] absolute fluxes and predict a correlation between [OI] and the sum $L_X + L_{FUV}$.

The data show no correlation between the [OI] line flux and the X-ray luminosity, the FUV luminosity or their sum. The data show that the FUV or X-ray radiation has no notable impact on the region where the [OI] line is formed. This is in contrast with what is predicted from our models. Possible explanations are that the disks in Taurus are less flaring than the hydrostatic models predict, and/or that other disk structure aspects that were left unchanged in our models are important.

Accepted by A&A

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EVN observations of 6.7 GHz methanol masers in clusters of massive young stellar objects.
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Methanol masers at 6.7 GHz are associated with high-mass star-forming regions (HMSFRs) and often have mid-infrared (MIR) counterparts characterized by extended emission at 4.5µm, which likely traces outflows from massive young stellar objects (MYSOs). Our objectives are to determine the milliarcsecond (mas) morphology of the maser emission and to examine if it comes from one or several candidate MIR counterparts in the clusters of MYSOs. The European VLBI Network (EVN) was used to image the 6.7 GHz maser line with ~2.1 arcmin field of view toward 14 maser sites from the Torun catalog. Quasi-simultaneous observations were carried out with the Torun 32m telescope. We obtained maps with mas angular resolution that showed diversity of methanol emission morphology: a linear distribution (e.g., G37.753−00.189), a ring-like (G40.425+00.700), and a complex one (e.g., G45.467+00.053). The maser emission is usually associated with the strongest MIR counterpart in the clusters; no maser emission was detected from other MIR sources in the fields of view of 2.1 arcmin in diameter. The maser source luminosity seems to correlate with the total luminosity of the central MYSO. Although the Very Long Baseline Interferometry (VLBI) technique resolves a significant part of the maser emission, the morphology is still well determined. This indicates that the majority of maser components have compact cores.

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**Principal Component Analysis of Molecular Clouds: Can CO reveal the dynamics?**

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We use Principal Component Analysis (PCA) to study the gas dynamics in numerical simulations of typical MCs. Our simulations account for the non-isothermal nature of the gas and include a simplified treatment of the time-dependent gas chemistry. We model the CO line emission in a post-processing step using a 3D radiative transfer code. We consider mean number densities \(n_0 = 30, 100, 300\) cm\(^{-3}\) that span the range of values typical for MCs in the solar neighbourhood and investigate the slope \(\alpha_{PCA}\) of the pseudo structure function computed by PCA for several components: the total density, \(H_2\) density, \(^{12}\)CO density, \(^{12}\)CO \(J = 1–0\) intensity and \(^{13}\)CO \(J = 1–0\) intensity.

We estimate power-law indices \(\alpha_{PCA}\) for different chemical species that range from 0.5 to 0.9, in good agreement with observations, and demonstrate that optical depth effects can influence the PCA. We show that when the PCA succeeds, the combination of chemical inhomogeneity and radiative transfer effects can influence the observed PCA slopes by as much as \(\sim \pm 0.1\). The method can fail if the CO distribution is very intermittent, e.g. in low-density clouds where CO is confined to small fragments.

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**Orion revisited. II. The foreground population to Orion A**

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Following the recent discovery of a large population of young stars in front of the Orion Nebula, we carried out an observational campaign with the DECam wide-field camera covering \(\sim 10\) deg\(^2\) centered on NGC 1980 to confirm, probe the extent of, and characterize this foreground population of pre-main-sequence stars. We confirm the presence of a large foreground population towards the Orion A cloud. This population contains several distinct subgroups, including NGC1980 and NGC1981, and stretches across several degrees in front of the Orion A cloud. By comparing the location of their sequence in various color-magnitude diagrams with other clusters, we found a distance and an age of 380 pc and 5–10 Myr, in good agreement with previous estimates. Our final sample includes 2123 candidate members and is complete from below the hydrogen-burning limit to about 0.3 \(M_\odot\), where the data start to be limited by saturation. Extrapolating the mass function to the high masses, we estimate a total number of \(\sim 2600\) members in the surveyed region. We confirm the presence of a rich, contiguous, and essentially coeval population of about 2600 foreground stars in front of the Orion A cloud, loosely clustered around NGC1980, NGC1981, and a new group in the foreground of the OMC-2/3. For the area of the cloud surveyed, this result implies that there are more young stars in the foreground population than young stars inside the cloud. Assuming a normal initial mass function, we estimate that between one to a few supernovae must have exploded in the foreground population in the past few million years, close to the surface of Orion A, which might be responsible, together with stellar winds, for the structure and star formation activity in these clouds. This long-overlooked foreground stellar population is of great significance, calling for a revision of the star formation history in this region of the Galaxy.

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The Spitzer Survey of Interstellar Clouds in the Gould Belt. VI. The Auriga-California Molecular Cloud observed with IRAC and MIPS

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We present observations of the Auriga-California Molecular Cloud (AMC) at 3.6, 4.5, 5.8, 8.0, 24, 70 and 160 μm observed with the IRAC and MIPS detectors as part of the Spitzer Gould Belt Legacy Survey. The total mapped areas are 2.5 sq-deg with IRAC and 10.47 sq-deg with MIPS. This giant molecular cloud is one of two in the nearby Gould Belt of star-forming regions, the other being the Orion A Molecular Cloud (OMC). We compare source counts, colors and magnitudes in our observed region to a subset of the SWIRE data that was processed through our pipeline. Using color-magnitude and color-color diagrams, we find evidence for a substantial population of 166 young stellar objects (YSOs) in the cloud, many of which were previously unknown. Most of this population is concentrated around the LkHα 101 cluster and the filament extending from it. We present a quantitative description of the degree of clustering and discuss the fraction of YSOs in the region with disks relative to an estimate of the diskless YSO population. Although the AMC is similar in mass, size and distance to the OMC, it is forming about 15 - 20 times fewer stars. Accepted by ApJ

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The Darkest Shadows: Deep Mid-Infrared Extinction Mapping of a Massive Protocluster

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We use deep 8μm Spitzer-IRAC imaging of a massive Infrared Dark Cloud (IRDC) to construct a Mid-Infrared (MIR)
extinction map that probes mass surface densities up to \( \Sigma \sim 1 \, \text{g cm}^{-2} \) \( (A_V \sim 200 \, \text{mag}) \), amongst the highest values yet probed by extinction mapping. Merging with a NIR extinction map of the region, creates a high dynamic range map that reveals structures down to \( A_V \sim 1 \, \text{mag} \). We utilize the map to: (1) Measure a cloud mass \( \sim 7 \times 10^4 \, M_\odot \) within a radius of \( \sim 8 \, \text{pc} \). \(^{13}\)CO kinematics indicate that the cloud is gravitationally bound. It thus has the potential to form one of the most massive young star clusters known in the Galaxy. (2) Characterize the structures of 16 massive cores within the IRDC, finding they can be fit by singular polytropic spheres with \( \rho \propto r^{-k_p} \) and \( k_p = 1.5 \pm 0.3 \). They have \( \Sigma \simeq 0.1 - 0.5 \, \text{g cm}^{-2} \) — relatively low values that, along with cold temperatures implied by their dark appearance at \( \sim 70 \, \mu \text{m} \), suggest magnetic fields, rather than accretion-powered radiative heating, are important for controlling fragmentation. (3) Determine the \( \Sigma \) (equivalently column density or \( A_V \)) probability distribution function (PDF) for a region that is near complete for \( A_V > 3 \, \text{mag} \). The PDF is well fit by a single log-normal with mean \( A_V \simeq 9 \, \text{mag} \), high compared to nearby clouds. It does not exhibit a separate high-end power law tail, which has been claimed to indicate the importance of self-gravity. However, we suggest that the PDF does result from a self-similar, self-gravitating hierarchy of structure being present over a wide range of scales in the cloud.

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A multiwavelength study of embedded clusters in W5-east, NGC 7538, S235, S252 and S254-S258

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We present Spitzer, near-IR (NIR) and millimetre observations of the massive star-forming regions W5-east, S235, S252, S254-S258 and NGC 7538. Spitzer data is combined with NIR observations to identify and classify the young population while 12CO and 13CO observations are used to examine the parental molecular cloud. We detect in total 3021 young stellar objects (YSOs). Of those, 539 are classified as Class I, and 1186 as Class II sources. YSOs are distributed in groups surrounded by a more scattered population. Class I sources are more hierarchically organized than Class II and associated with the most dense molecular material. We identify in total 41 embedded clusters containing between 52 and 73 percent of the YSOs. Clusters are in general non-virialized, turbulent and have star formation efficiencies between 5 and 50 percent. We compare the physical properties of embedded clusters harbouring massive stars (MEC) and low-mass embedded clusters (LEC) and find that both groups follow similar correlations where the MEC are an extrapolation of the LEC. The mean separation between MEC members is smaller compared to the cluster Jeans length than for LEC members. These results are in agreement with a scenario where stars are formed in hierarchically distributed dusty filaments where fragmentation is mainly driven by turbulence for the more massive clusters. We find several young OB-type stars having IR-excess emission which may be due to the presence of an accretion disc.

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http://mnras.oxfordjournals.org/content/early/2014/02/26/mnras.stu224.full.pdf?keytype=ref&ijkey=fO0N94AQEIKI

The Phases of Water Ice in the Solar Nebula

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Understanding the phases of water ice that were present in the solar nebula has implications for understanding cometary and planetary compositions as well as internal evolution of these bodies. Here we show that amorphous ice formed
more readily than previously recognized, with formation at temperatures <70 K being possible under protoplanetary disk conditions. We further argue that photodesorption and freeze-out of water molecules near the surface layers of the solar nebula would have provided the conditions needed for amorphous ice to form. This processing would be a natural consequence of ice dynamics, and would allow for the trapping of noble gases and other volatiles in water ice in the outer solar nebula.

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The role of turbulence in star formation laws and thresholds

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The Schmidt-Kennicutt relation links the surface densities of gas to the star formation rate in galaxies. The physical origin of this relation, and in particular its break, i.e. the transition between an inefficient regime at low gas surface densities and a main regime at higher densities, remains debated. Here, we study the physical origin of the star formation relations and breaks in several low-redshift galaxies, from dwarf irregulars to massive spirals. We use numerical simulations representative of the Milky Way, the Large and the Small Magellanic Clouds with parsec up to subparsec resolution, and which reproduce the observed star formation relations and the relative variations of the star formation thresholds. We analyze the role of interstellar turbulence, gas cooling, and geometry in drawing these relations, at 100 pc scale. We suggest in particular that the existence of a break in the Schmidt-Kennicutt relation could be linked to the transition from subsonic to supersonic turbulence and is independent of self-shielding effects. This transition being connected to the gas thermal properties and thus to the metallicity, the break is shifted toward high surface densities in metal-poor galaxies, as observed in dwarf galaxies. Our results suggest that together with the collapse of clouds under self-gravity, turbulence (injected at galactic scale) can induce the compression of gas and regulate star formation.

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Chemical abundances of the high-latitude Herbig Ae Star PDS2

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The Herbig Ae star PDS2 (CD -53 251) is unusual in several ways. It has a high Galactic latitude, unrelated to any known star-forming region. It is at the cool end of the Herbig Ae sequence, where favorable circumstances facilitate the determination of stellar parameters and chemical abundances. We find $T_{\text{eff}} = 6500$ K, and $\log(g) = 3.5$. The relatively low $v \cdot \sin(i) = 12 \pm 2$ km s$^{-1}$ made it possible to use mostly weak lines for the abundances. PDS2 appears to belong to the class of Herbig Ae stars with normal volatile and depleted involatile elements. This pattern is seen not only in λ Boo stars, but in some post AGB and RV Tauri stars. The appearance of the same abundance pattern in young stars and highly evolved giants strengthens the hypothesis of gas-grain separation for its origin. The intermediate volatile zinc can violate the pattern of depleted volatiles.
Molecules, dust, and protostars in NGC 3503

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We are presenting here a follow-up study of the molecular gas and dust in the environs of the star forming region NGC 3503. This study aims at dealing with the interaction of NGC 3503 with its parental molecular cloud, and also with the star formation in the region. To analyze the molecular gas we use CO (2–1), 13CO (2–1), C18O (2–1), and HCN (3–2) line data obtained with the APEX telescope. To study the distribution of the dust, we make use of images at 870 µm from the ATLASGAL survey and IRAC-GLIMPSE archival images. We use public 2MASS and WISE data to search for candidate YSOs in the region. The new APEX observations allowed the substructure of the molecular gas in the velocity range from −28 to −23 km s−1 to be imaged in detail. The morphology of the molecular gas close to the nebula, the location of the PDR, and the shape of radio continuum emission suggest that the ionized gas is expanding against its parental cloud, and confirm the “champagne flow” scenario. We have identified several molecular clumps and determined some of their physical and dynamical properties. We have compared the physical properties of the clumps to investigate how the molecular gas has been affected by the HII region. Clumps adjacent to the ionization fronts of NGC 3503 and/or the bright rimmed cloud SFO62 have been heated and compressed by the ionized gas, but their line width is not different to those that are too distant to the ionization fronts. We identified several candidate YSOs in the region. Their spatial distribution suggests that stellar formation might have been boosted by the expansion of the nebula. We discard the “collect and collapse” scenario and propose alternative mechanisms such as radiatively driven implosion on pre-existing molecular clumps or small-scale Jeans gravitational instabilities.

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A WISE Survey of Circumstellar Disks in Taurus

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We have compiled photometry at 3.4, 4.6, 12 and 22 µm from the all-sky survey performed by the Wide-field Infrared Survey Explorer (WISE) for all known members of the Taurus complex of dark clouds. Using these data and photometry from the Spitzer Space Telescope, we have identified members with infrared excess emission from circumstellar disks and have estimated the evolutionary stages of the detected disks, which include 31 new full disks and 16 new candidate transitional, evolved, evolved transitional, and debris disks. We have also used the WISE All-Sky Source Catalog to search for new disk-bearing members of Taurus based on their red infrared colors. Through optical and near-infrared spectroscopy, we have confirmed 26 new members with spectral types of M1–M7. The census of disk-bearing stars in Taurus should now be largely complete for spectral types earlier than ~M8 (M ≥ 0.03 M⊙).

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Thermodynamics of the dead-zone inner edge in protoplanetary disks

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In protoplanetary disks, the inner boundary between the turbulent and laminar regions could be a promising site for planet formation, thanks to the trapping of solids at the boundary itself or in vortices generated by the Rossby wave instability. At the interface, the disk thermodynamics and the turbulent dynamics are entwined because of the importance of turbulent dissipation and thermal ionization. Numerical models of the boundary, however, have neglected the thermodynamics, and thus miss a part of the physics. The aim of this paper is to numerically investigate the interplay between thermodynamics and dynamics in the inner regions of protoplanetary disks by properly accounting for turbulent heating and the dependence of the resistivity on the local temperature. Using the Godunov code RAMSES, we performed a series of 3D global numerical simulations of protoplanetary disks in the cylindrical limit, including turbulent heating and a simple prescription for radiative cooling. We find that waves excited by the turbulence significantly heat the dead zone, and we subsequently provide a simple theoretical framework for estimating the wave heating and consequent temperature profile. In addition, our simulations reveal that the dead-zone inner edge can propagate outward into the dead zone, before stalling at a critical radius that can be estimated from a mean-field model. The engine driving the propagation is in fact density wave heating close to the interface. A pressure maximum appears at the interface in all simulations, and we note the emergence of the Rossby wave instability in simulations with extended azimuth. Our simulations illustrate the complex interplay between thermodynamics and turbulent dynamics in the inner regions of protoplanetary disks. They also reveal how important activity at the dead-zone interface can be for the dead-zone thermodynamic structure.

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DNC/HNC and N₂D⁺/N₂H⁺ ratios in high-mass star forming cores

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Chemical models predict that the deuterated fraction (the column density ratio between a molecule containing D and its counterpart containing H) of N₂H⁺, \( D_{\text{trac}}(\text{N}_2\text{H}^+) \), is high in massive pre-protostellar cores and rapidly drops of an order of magnitude after the protostar birth, while that of HNC, \( D_{\text{trac}}(\text{HNC}) \), remains constant for much longer. We tested these predictions by deriving \( D_{\text{trac}}(\text{HNC}) \) in 22 high-mass star forming cores divided in three different evolutionary stages, from high-mass starless core candidates (HMSCs, 8) to high-mass protostellar objects (HMPOs, 7) to Ultracompact HII regions (UCHIIs, 7). For all of them, \( D_{\text{trac}}(\text{N}_2\text{H}^+) \) was already determined through IRAM-30m Telescope observations, which confirmed the theoretical rapid decrease of \( D_{\text{trac}}(\text{N}_2\text{H}^+) \) after protostar birth (Fontani et al. 2011). Therefore our comparative study is not affected by biases introduced by the source selection. We have found average \( D_{\text{trac}}(\text{HNC}) \) of 0.012, 0.009 and 0.008 in HMSCs, HMPOs and UCHIIs, respectively, with no statistically significant differences among the three evolutionary groups. These findings confirm the predictions of the chemical models, and indicate that large values of \( D_{\text{trac}}(\text{N}_2\text{H}^+) \) are more suitable than large values of \( D_{\text{trac}}(\text{HNC}) \) to identify cores on the verge of forming high-mass stars, likewise what found in the low-mass regime.

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Triple trouble for XZ Tau: deep imaging with the Jansky Very Large Array
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We present new observations of the XZ Tau system made at high angular resolution (55 milliarcsecond) with the Karl G. Jansky Very Large Array (VLA) at a wavelength of 7 mm. Observations of XZ Tau made with the VLA in 2004 appeared to show a triple system, with XZ Tau A resolved into two sources, XZ Tau A and XZ Tau C. The angular separation of XZ Tau A and C (0.09) suggested a projected orbital separation of around 13 AU with a possible orbital period of around 40 yr. Our observations were obtained approximately 8 yr later, a fifth of this putative orbital period, and should therefore allow us to constrain the orbit of XZ Tau C, and evaluate the possibility that a recent periastron passage of C coincided with the launch of extended optical outflows from XZ Tau A. Despite improved sensitivity and resolution compared with previous observations, we find no evidence of XZ Tau C in our data. Components A and B are detected with a signal-to-noise ratio greater than ten; their orbits are consistent with previous studies, although the emission from XZ Tau A appears to be weaker. Three possible interpretations are offered: either XZ Tau C is transiting XZ Tau A, which is broadly consistent with the periastron passage hypothesis, or the emission seen in 2004 was that of a transient, or XZ Tau C does not exist. A fourth interpretation, that XZ Tau C was ejected from the system, is dismissed due to the lack of angular momentum redistribution in the orbits of XZ Tau A and XZ Tau B that would result from such an event. Our observations are insufficient to distinguish between the remaining possibilities, at least not until we obtain further VLA observations at a sufficiently later time. A further non-detection would allow us to reject the transit hypothesis, and the periastron passage of XZ Tau C as agent of XZ Tau A’s outflows.

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High-resolution Ultraviolet Radiation Fields of Classical T Tauri Stars
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The far-ultraviolet (FUV; 912–1700 Å) radiation field from accreting central stars in Classical T Tauri systems influences the disk chemistry during the period of giant planet formation. Previous efforts to measure the true stellar+accretion-generated FUV luminosity (both hot gas emission lines and continua) have been complicated by a combination of low-sensitivity and/or low-spectral resolution and did not include the contribution from the bright Lyα emission line. In this work, we present a high-resolution spectroscopic study of the FUV radiation fields of 16 T Tauri stars whose dust disks display a range of evolutionary states. We include reconstructed Lyα line profiles and remove atomic and molecular disk emission (from H2 and CO fluorescence) to provide robust measurements of both the FUV continuum and hot gas lines (e.g., Lyα, N V, C IV, He II) for an appreciable sample of T Tauri stars for the first time. We find that the flux of the typical Classical T Tauri Star FUV radiation field at 1 AU from the central star is ~107 times the average interstellar radiation field. The Lyα emission line contributes an average of 88% of the total FUV flux, with the FUV continuum accounting for an average of 8%. Both the FUV continuum and Lyα flux are strongly correlated with C IV flux, suggesting that accretion processes dominate the production of both of these components. On average, only ~0.5% of the total FUV flux is emitted between the Lyman limit (912 Å) and the H2 (0 – 0) absorption band at 1110 Å. The total and component-level high-resolution radiation fields are made publicly available in machine-readable format.
On the Viability of the Magnetorotational Instability in Circumplanetary Disks
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We examine whether the magnetorotational instability (MRI) can serve as a mechanism of angular momentum transport in circumplanetary disks. For the MRI to operate the ionization degree must be sufficiently high and the magnetic pressure must be sufficiently lower than the gas pressure. We calculate the spatial distribution of the ionization degree and search for the MRI-active region where the two criteria are met. We find that there can be thin active layers at the disk surface depending on the model parameters, however, we find hardly any region which can sustain well-developed MRI turbulence; when the magnetic field is enhanced by MRI turbulence at the disk surface layer, a magnetically dominated atmosphere encroaches on a lower altitude and a region of well-developed MRI turbulence becomes smaller. We conclude that if there are no angular momentum transfer mechanisms other than MRI in gravitationally stable circumplanetary disks, gas is likely to pile up until disks become gravitationally unstable, and massive disks may survive for a long time.

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Giant molecular clouds and massive star formation in the southern milky way
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The Columbia - U. de Chile CO Survey of the Southern Milky Way is used for separating the CO (1–0) emission of the fourth Galactic quadrant within the solar circle into its dominant components, giant molecular clouds (GMCs). After the subtraction of an axisymmetric model of the CO background emission in the inner Southern Galaxy, 92 GMCs are identified, and for 87 of them the two-fold distance ambiguity is solved. Their total molecular mass is \( M(H_2) = 1.14 \pm 0.05 \times 10^8 \, M_\odot \) accounting for around 40\% of the molecular mass estimated from an axisymmetric analysis of the \( H_2 \) volume density in the Galactic disk (Bronfman et al. 1988b) \( M(H_2)_{\text{disk}} = 3.03 \times 10^8 \, M_\odot \). The large scale spiral structure in the Southern Galaxy, within the solar circle, is traced by the GMCs in our catalog; 3 spiral arm segments: the Centaurus, Norma, and 3-kpc expanding arm are analyzed. After fitting a logarithmic spiral arm model to the arms, tangent directions at 310\textdegree, 330\textdegree, and 338\textdegree, respectively, are found, consistent with previous values from the literature. A complete CS (2–1) survey toward IRAS point-like sources with FIR colors characteristic of UC HII regions is used to estimate the massive star formation rate per unit \( H_2 \) mass (MSFR), and the massive star formation efficiency for GMCs. The average MSFR for GMCs is 0.41\pm0.06 \( L_\odot/M_\odot \), and for the most massive clouds in the Norma arm it is 0.58\pm0.09 \( L_\odot/M_\odot \). Massive star formation efficiencies of GMCs are on average 3\% of their available molecular mass.

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The Complex Distribution of Recently Formed Stars. Bimodal Stellar Clustering in the
Star-Forming Region NGC 346

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We present a detailed stellar clustering analysis with the application of the two-point correlation function on distinct young stellar ensembles. Our aim is to understand how stellar systems are assembled at the earliest stages of their formation. Our object of interest is the star-forming region NGC 346 in the Small Magellanic Cloud. It is a young stellar system well-revealed from its natal environment, comprising complete samples of pre–main-sequence and upper main-sequence stars, very close to their formation. We apply a comprehensive characterization of the autocorrelation function for both centrally condensed stellar clusters and self-similar stellar distributions through numerical simulations of stellar ensembles. We interpret the observed autocorrelation function of NGC 346 on the basis of these simulations. We find that it can be best explained as the combination of two distinct stellar clustering designs, a centrally concentrated, dominant at the central part of the star-forming region, and an extended self-similar distribution of stars across the complete observed field. The cluster component, similar to non-truncated young star clusters, is determined to have a core radius of $\sim 2.5$ pc and a density profile index of $\sim 2.3$. The extended fractal component is found with our simulations to have a fractal dimension of $\sim 2.3$, identical to that found for the interstellar medium, in agreement to hierarchy induced by turbulence. This suggests that the stellar clustering at a time very near to birth behaves in a complex manner. It is the combined result of the star formation process regulated by turbulence and the early dynamical evolution induced by the gravitational potential of condensed stellar clusters.

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SED analysis of class I and class II FU Orionis stars

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FU Orionis stars (FUORS) are eruptive pre-main sequence objects thought to represent quasi-periodic or recurring stages of enhanced accretion during the low-mass star-forming process. We characterize the sample of known and candidate FUORS in an homogeneous and consistent way, deriving stellar and circumstellar parameters for each object. We emphasize the analysis in those parameters that are supposed to vary during the FUORS stage. We modeled the SEDs of 24 of the 26 currently known FUORS, using the radiative transfer code of Whitney et al. (2003b). We compare our models with those obtained by Robitaille et al. (2007) for Taurus class II and I sources in quiescence periods, by calculating the cumulative distribution of the different parameters. FUORS have more massive disks: we find that $\sim 80\%$ of the disks in FUORS are more massive than any Taurus class II and I sources in the sample. Median values for the disk mass accretion rates are $\sim 10^{-7} M_\odot$/yr vs $\sim 10^{-5} M_\odot$/yr for standard YSOs (young stellar objects) and FUORS, respectively. While the distributions of envelope mass accretion rates for class I FUORS and for standard class I objects are similar, FUORS, on average, have higher envelope mass accretion rates than standard class II and class I sources. Most FUORS ($\sim 70\%$) have envelope mass accretion rates above $10^{-7} M_\odot$/yr. In contrast, 60% of the classical YSO sample have accretion rates below this value. Our results support the current scenario in which changes experimented by the circumstellar disk explain the observed properties of these stars. However, the increase in the disk mass accretion rate is smaller than theoretically predicted (Frank et al. 1992, Hartmann et al. 1996a), though in good agreement with previous determinations.

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The ionizing sources of luminous compact HII regions in the RCW106 and RCW122 clouds
Context. Given the rarity of young O star candidates, compact HII regions embedded in dense molecular cores continue to serve as potential sites for peering into the details of high-mass star formation.

Aims. We uncover the ionizing sources of the most luminous and compact HII regions embedded in the RCW106 and RCW122 giant molecular clouds, known to be relatively nearby (2-4 kpc) and isolated, thus providing an opportunity to examine spatial scales of a few hundred to a thousand AU in size.

Methods. High spatial resolution (0.3''), mid-infrared spectra (R=350), including the fine structure lines [ArIII] and [NeII], were obtained for four luminous compact HII regions embedded inside the dense cores within the RCW106 and RCW122 molecular cloud complexes. At this resolution, these targets reveal point-like sources surrounded by the nebulosity of different morphologies, thereby uncovering details at spatial dimensions of <1000AU. The point-like sources display [ArIII] and [NeII] lines - the ratios of which are used to estimate the effective temperature of the embedded sources.

Results. The derived temperatures are indicative of mid-late O type objects for all the sources with [ArIII] emission. Previously known characteristics of these targets from the literature, including evidence of disk or accretion, suggest that the identified sources may grow more to become early-type O stars by the end of the star formation process.

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SMA millimeter observations of Hot Molecular Cores

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We present Submillimeter Array observations, in the 1.3 mm continuum and the CH3CN (12K–11K) line of 17 hot molecular cores associated with young high-mass stars. The angular resolution of the observations ranges from 1.0'' to 4.0''. The continuum observations reveal large (>3500 AU) dusty structures with gas masses from 7 to 375 M_☉, that probably surround multiple young stars. The CH3CN line emission is detected toward all the molecular cores at least up to the K = 6-component and is mostly associated with the emission peaks of the dusty objects. We used the multiple K-components of the CH3CN and both the rotational diagram method and a simultaneous synthetic LTE model with the XCLASS program to estimate the temperatures and column densities of the cores. For all sources, we obtained reasonable fits from XCLASS by using a model that combines two components: an extended and warm envelope, and a compact hot core of molecular gas, suggesting internal heating by recently formed massive stars. The rotational temperatures lie in the range of 40-132 K and 122-485 K for the extended and compact components, respectively. From the continuum and CH3CN results, we infer fractional abundances from 10^{−9} to 10^{−7} toward the compact inner components, that increase with the rotational temperature. Our results agree with a chemical scenario in which the CH3CN molecule is efficiently formed in the gas phase above 100-300 K, and its abundance increases with temperature.

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B fields in OB stars (BOB): The discovery of a magnetic field in a multiple system in the Trifid Nebula, one of the youngest star forming regions

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Recent magnetic field surveys in O- and B-type stars revealed that about 10% of the core-hydrogen-burning massive stars host large-scale magnetic fields. The physical origin of these fields is highly debated. To identify and model the physical processes responsible for the generation of magnetic fields in massive stars, it is important to establish whether magnetic massive stars are found in very young star-forming regions or whether they are formed in close interacting binary systems.

In the framework of our ESO Large Program, we carried out low-resolution spectropolarimetric observations with FORS2 in 2013 April of the three most massive central stars in the Trifid nebula, HD 164492A, HD 164492C, and HD 164492D. These observations indicated a strong longitudinal magnetic field of about 500–600 G in the poorly studied component HD 164492C. To confirm this detection, we used HARPS in spectropolarimetric mode on two consecutive nights in 2013 June.

Our HARPS observations confirmed the longitudinal magnetic field in HD 164492C. Furthermore, the HARPS observations revealed that HD 164492C cannot be considered as a single star as it possesses one or two companions. The spectral appearance indicates that the primary is most likely of spectral type B1–B1.5 V. Since in both observing nights most spectral lines appear blended, it is currently unclear which components are magnetic. Long-term monitoring using high-resolution spectropolarimetry is necessary to separate the contribution of each component to the magnetic signal. Given the location of the system HD 164492C in one of the youngest star formation regions, this system can be considered as a Rosetta Stone for our understanding of the origin of magnetic fields in massive stars.

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Transport of solids in protoplanetary disks: Comparing meteorites and astrophysical models

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We review models of chondrite component transport in the gaseous protoplanetary disk. Refractory inclusions were likely transported by turbulent diffusion and possible early disk expansion, and required low turbulence for their subsequent preservation in the disk, possibly in a dead zone. Chondrules were produced locally but did not necessarily accrete shortly after formation. Water may have been enhanced in the inner disk because of inward drift of solids from further out, but likely not by more than a factor of a few. Incomplete condensation in chondrites may be due to slow reaction kinetics during temperature decrease. While carbonaceous chondrite compositions might be reproduced in a “two-component” picture (Anders 1964), such components would not correspond to simple petrographic constituents, although part of the refractory element fractionations in chondrites may be due to the inward drift of refractory inclusions. Overall, considerations of chondrite component transport alone favor an earlier formation for carbonaceous chondrites relative to their noncarbonaceous counterparts, but independent objections have yet to be resolved.

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Accretion in giant planet circumplanetary disks

Sarah L. Keith and Mark Wardle

Sarah L. Keith, Mark Wardle
During the final growth phase of giant planets, accretion is thought to be controlled by a surrounding circumplanetary disk. Current astrophysical accretion disk models rely on hydromagnetic turbulence or gravitoturbulence as the source of effective viscosity within the disk. However, the magnetically-coupled accreting region in these models is so limited that the disk may not support inflow at all radii, or at the required rate. Here, we examine the conditions needed for self-consistent accretion, in which the disk is susceptible to accretion driven by magnetic fields or gravitational instability. We model the disk as a Shakura-Sunyaev $\alpha$ disk and calculate the level of ionisation, the strength of coupling between the field and disk using Ohmic, Hall and Ambipolar diffusivities for both an MRI and vertical field, and the strength of gravitational instability. We find that the standard constant-$\alpha$ disk is only coupled to the field by thermal ionisation within $30 R_J$ with strong magnetic diffusivity prohibiting accretion through the bulk of the midplane. In light of the failure of the constant-$\alpha$ disk to produce accretion consistent with its viscosity we drop the assumption of constant-$\alpha$ and present an alternate model in which varies radially according to the level magnetic turbulence or gravitoturbulence. We find that a vertical field may drive accretion across the entire disk, whereas MRI can drive accretion out to $\sim 200 R_J$, beyond which Toomre’s $Q = 1$ and gravitoturbulence dominates. The disks are relatively hot ($T \gtrsim 800$ K), and consequently massive ($M_{\text{disk}} \sim 0.5 M_J$).

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Migration of Earth-size planets in 3D radiative discs

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In this paper, we address the migration of small mass planets in 3D radiative disks. Indeed, migration of small planets is known to be too fast inwards in locally isothermal conditions. However, thermal effects could reverse its direction, potentially saving planets in the inner, optically thick parts of the protoplanetary disc. This effect has been seen for masses larger than 5 Earth masses, but the minimum mass for this to happen has never been probed numerically, although it is of crucial importance for planet formation scenarios. We have extended the hydro-dynamical code FARGO to 3D, with thermal diffusion. With this code, we perform simulations of embedded planets down to 2 Earth masses. For a set of discs parameters for which outward migration has been shown in the range of [5,35] Earth masses, we find that the transition to inward migration occurs for masses in the range [3,5] Earth masses. The transition appears to be due to an unexpected phenomenon: the formation of an asymmetric cold and dense finger of gas driven by circulation and libration streamlines. We recover this phenomenon in 2D simulations where we control the cooling effects of the gas through a simple modeling of the energy equation.

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Forming Circumbinary Planets: N-body Simulations of Kepler-34

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Observations of circumbinary planets orbiting very close to the central stars have shown that planet formation may occur in a very hostile environment, where the gravitational pull from the binary should be very strong on the primordial protoplanetary disk. Elevated impact velocities and orbit crossings from eccentricity oscillations are the primary contributors towards high energy, potentially destructive collisions that inhibit the growth of aspiring planets.

In this work, we conduct high resolution, inter-particle gravity enabled N-body simulations to investigate the feasibility of planetesimal growth in the Kepler-34 system. We improve upon previous work by including planetesimal disk self-gravity and an extensive collision model to accurately handle inter-planetesimal interactions. We find that super-catastrophic erosion events are the dominant mechanism up to and including the orbital radius of Kepler-34(AB)b, making in-situ growth unlikely. It is more plausible that Kepler-34(AB)b migrated from a region beyond 1.5 AU. Based on the conclusions that we have made for Kepler-34 it seems likely that all of the currently known circumbinary planets have also migrated significantly from their formation location with the possible exception of Kepler-47(AB)c.

Zhu, Stone, and Rafikov (2012) found in 3D shearing box simulations a new form of planet-disk interaction that they attributed to a vertical buoyancy resonance in the disk. We describe an analytic linear model for this interaction. We adopt a simplified model involving azimuthal forcing that produces the resonance and permits an analytic description of its structure. We derive an analytic expression for the buoyancy torque and show that the vertical torque distribution agrees well with results of Athena simulations and a Fourier method for linear numerical calculations carried out with the same forcing. The buoyancy resonance differs from the classic Lindblad and corotation resonances in that the resonance lies along tilted planes. Its width depends on damping effects and is independent of the gas sound speed. The resonance does not excite propagating waves. At a given large azimuthal wavenumber $k_y > h^{-1}$ (for disk thickness $h$), the buoyancy resonance exerts a torque over a region that lies radially closer to the corotation radius than the Lindblad resonance. Because the torque is localized to the region of excitation, it is potentially subject to the effects of nonlinear saturation. In addition, the torque can be reduced by the effects of radiative heat transfer between the resonant region and its surroundings. For each azimuthal wavenumber, the resonance establishes a large scale density wave pattern in a plane within the disk.

We present an all-sky sample of 984 candidate intermediate-mass Galactic star-forming regions color-selected from the Infrared Astronomical Satellite (IRAS) Point Source Catalog and morphologically classify each object using mid-infrared Wide-field Infrared Survey Explorer (WISE) images. Of the 984 candidates, 616 are probable star-forming regions (62.6%), 128 are filamentary structures (13.0%), 39 are point-like objects of unknown nature (4.0%), and 26
201 are galaxies (20.4%). We conduct a study of four of these regions, IRAS 00259+5625, IRAS 00420+5530, IRAS 01080+5717, and IRAS 05380+2020, at Galactic latitudes $|b| > 5^\circ$ using optical spectroscopy from the Wyoming Infrared Observatory along with near-infrared photometry from the Two-Micron All Sky Survey to investigate their stellar content. New optical spectra, color-magnitude diagrams, and color-color diagrams reveal their extinctions, spectrophotometric distances, and the presence of small stellar clusters containing 20–78 $M_\odot$ of stars. These low-mass diffuse star clusters contain 65–250 stars for a typical initial mass function, including one or more mid-B stars as their most massive constituents. Using infrared spectral energy distributions we identify young stellar objects near each region and assign probable masses and evolutionary stages to the protostars. The total infrared luminosity lies in the range 190 to 960 $L_\odot$, consistent with the sum of the luminosities of the individually identified young stellar objects.

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Polycyclic aromatic hydrocarbon ionization as a tracer of gas flows through protoplanetary disk gaps

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Planet-forming disks of gas and dust around young stars contain polycyclic aromatic hydrocarbons (PAHs). We aim to characterize how the charge state of PAHs can be used as a probe of flows of gas through protoplanetary gaps. In this context, our goal is to understand the PAH spectra of four transitional disks. In addition, we want to explain the observed correlation between PAH ionization (traced by the 6.2/11.3 feature ratio) and the disk mass (traced by the 1.3 mm luminosity). We implement a model to calculate the charge state of PAHs in the radiative transfer code MCMx. The emission spectra and ionization balance are calculated. A benchmark modeling grid is presented that shows how PAH ionization and luminosity behave as a function of star and disk properties. The PAH ionization is most sensitive to ultraviolet (UV) radiation and the electron density. In optically thick disks, where the UV field is low and the electron density is high, PAHs are predominantly neutral. Ionized PAHs trace low-density optically thin disk regions where the UV field is high and the electron density is low. Such regions are characteristic of gas flows through the gaps of transitional disks. We demonstrate that fitting the PAH spectra of four transitional disks requires a contribution of ionized PAHs in gas flows through the gap. The PAH spectra of transitional disks can be understood as superpositions of neutral and ionized PAHs. For HD97048, neutral PAHs in the optically thick disk dominate the spectrum. In the cases of HD169142, HD135344B and Oph IRS 48, small amounts of ionized PAHs located in the gas flows through the gap are strong contributors to the total PAH luminosity. The observed trend between the disk mass and PAH ionization may imply that lower-mass disks have larger gaps. Ionized PAHs in gas flows through these gaps contribute strongly to their spectra.

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Conditions for Circumstellar Disk Formation: Effects of Initial Cloud Configuration and Sink Treatment

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The formation of a circumstellar disk in collapsing cloud cores is investigated with three-dimensional magnetohydrodynamic simulations. We prepare four types of initial cloud having different density profiles and calculate their evolution
Multiwavelength study of the high-latitude cloud L1642: chain of star formation

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L1642 is one of the two high galactic latitude (|b| > 30°) clouds confirmed to have active star formation. We examine the properties of this cloud, especially the large-scale structure, dust properties, and compact sources in different stages of star formation. We present high-resolution far-infrared and submillimetre observations with the Herschel and AKARI satellites and millimetre observations with the AzTEC/ASTE telescope, which we combined with archive data from near- and mid-infrared (2MASS, WISE) to millimetre wavelength observations (Planck). The Herschel observations, combined with other data, show a sequence of objects from a cold clump to young stellar objects at different evolutionary stages. Source B-3 (2MASS 04351455-1414468) appears to be a YSO forming inside the L1642 cloud, instead of a foreground brown dwarf, as previously classified. Herschel data reveal striation in the diffuse dust emission around the cloud L1642. The western region shows striation towards the NE and has a steeper column density gradient on its southern side. The densest central region has a bow-shock like structure showing compression from the west and has a filamentary tail extending towards the east. The differences suggest that these may be spatially distinct structures, aligned only in projection. We derive values of the dust emission cross-section per H nucleon of $\sigma_e(250\mu m) = 0.5-1.5 \times 10^{-25} \text{cm}^2/\text{H}$ for different regions of the cloud. Modified black-body fits to the spectral
energy distribution of Herschel and Planck data give emissivity spectral index $\beta$ values 1.8–2.0 for the different regions. The compact sources have lower $\beta$ values and show an anticorrelation between $T$ and $\beta$. Markov chain Monte Carlo calculations demonstrate the strong anticorrelation between $\beta$ and $T$ errors and the importance of millimetre wavelength Planck data in constraining the estimates. L1642 reveals a more complex structure and sequence of star formation than previously known.

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New constraints on the formation and settling of dust in the atmospheres of young M and L dwarfs

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We obtained medium-resolution near-infrared spectra of seven young M9.5–L3 dwarfs classified in the optical. We aim to confirm the low surface gravity of the objects in the NIR. We also test whether atmospheric models correctly represent the formation and the settling of dust clouds in the atmosphere of young late-M and L dwarfs. We used ISAAC at VLT to obtain the spectra of the targets. We compared them to those of mature and young BD, and young late-type companions to nearby stars with known ages, in order to identify and study gravity-sensitive features. We computed spectral indices weakly sensitive to the surface gravity to derive near-infrared spectral types. Finally, we found the best fit between each spectrum and synthetic spectra from the BT-Settl 2010 and 2013 models. Using the best fit, we derived the atmospheric parameters of the objects and identify which spectral characteristics the models do not reproduce. We confirmed that our objects are young BD and we found NIR spectral types in agreement with the ones determined at optical wavelengths. The spectrum of the L2γ dwarf 2MASSJ2322−6151 reproduces well the spectrum of the planetary mass companion 1RXS J1609−2105b. BT-Settl models fit the spectra and the 1–5 $\mu$m SED of the L0–L3 dwarfs for temperatures between 1600–2000 K. But the models fail to reproduce the shape of the H band, and the NIR slope of some of our targets. This fact, and the best fit solutions found with super-solar metallicity are indicative of a lack of dust, in particular at high altitude, in the cloud models. The modeling of the vertical mixing and of the grain growth will be revised in the next version of the BT-Settl models. These revisions may suppress the remaining non-reproducibilities.

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On the evolution of the CO snow line in protoplanetary disks

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CO is thought to be a vital building block for prebiotic molecules that are necessary for life. Thus, understanding where CO existed in a solid phase within the solar nebula is important for understanding the origin of life. We model the evolution of the CO snow line in a protoplanetary disk. We find that the current observed location of the CO snow line in our solar system, and in the solar system analogue TW Hydra, cannot be explained by a fully turbulent
disk model. With time-dependent disk models we find that the inclusion of a dead zone (a region of low turbulence) can resolve this problem. Furthermore, we obtain a fully analytic solution for the CO snow line radius for late disk evolutionary times. This will be useful for future observational attempts to characterize the demographics and predict the composition and habitability of exoplanets.

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On the structure of the transition disk around TW Hya


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For over a decade, the structure of the inner cavity in the transition disk of TW Hydrae has been a subject of debate. Modeling the disk with data obtained at different wavelengths has led to a variety of proposed disk structures. Rather than being inconsistent, the individual models might point to the different faces of physical processes going on in disks, such as dust growth and planet formation. Our aim is to investigate the structure of the transition disk again and to find to what extent we can reconcile apparent model differences. A large set of high-angular-resolution data was collected from near-infrared to centimeter wavelengths. We investigated the existing disk models and established a new self-consistent radiative-transfer model. A genetic fitting algorithm was used to automatize the parameter fitting. Simple disk models with a vertical inner rim and a radially homogeneous dust composition from small to large grains cannot reproduce the combined data set. Two modifications are applied to this simple disk model: (1) the inner rim is smoothed by exponentially decreasing the surface density in the inner $\sim$3 AU, and (2) the largest grains ($>$100 $\mu$m) are concentrated towards the inner disk region. Both properties can be linked to fundamental processes that determine the evolution of protoplanetary disks: the shaping by a possible companion and the different regimes of dust-grain growth, respectively. The full interferometric data set from near-infrared to centimeter wavelengths requires a revision of existing models for the TW Hya disk. We present a new model that incorporates the characteristic structures of previous models but deviates in two key aspects: it does not have a sharp edge at 4 AU, and the surface density of large grains differs from that of smaller grains. This is the first successful radiative-transfer-based model for a full set of interferometric data.

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Substellar Objects in Nearby Young Clusters (SONYC) VIII: Substellar population in Lupus 3

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SONYC – Substellar Objects in Nearby Young Clusters – is a survey programme to investigate the frequency and properties of substellar objects in nearby star-forming regions. We present a new imaging and spectroscopic survey conducted in the young (∼ 1 Myr), nearby (∼ 200 pc) star-forming region Lupus 3. Deep optical and near-infrared images were obtained with MOSAIC-II and NEWFIRM at the CTIO-4m telescope, covering ∼ 1.4 deg2 on the sky. The i-band completeness limit of 20.3 mag is equivalent to 0.009 − 0.02 M⊙, for AV ≤ 5. Photometry and 11−12 yr baseline proper motions were used to select candidate low-mass members of Lupus 3. We performed spectroscopic follow-up of 123 candidates, using VIMOS at the Very Large Telescope (VLT), and identify 7 probable members, among which 4 have spectral type later than M6.0 and Teff ≤ 3000 K, i.e. are probably substellar in nature. Two of the new probable members of Lupus 3 appear underluminous for their spectral class and exhibit emission line spectrum with strong Hα or forbidden lines associated with active accretion. We derive a relation between the spectral type and effective temperature: Teff = (4120 ± 175) − (172 ± 26) × SpT, where SpT refers to the M spectral subtype between 1 and 9. Combining our results with the previous works on Lupus 3, we show that the spectral type distribution is consistent with that in other star forming regions, as well as is the derived star-to-BD ratio of 2.0 − 3.3. We compile a census of all spectroscopically confirmed low-mass members with spectral type M0 or later.

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The Young Stellar Cluster in the Vicinity of the IRAS 05137+3919 Source

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On the basis of UKIDSS data and Spitzer (IRAC) images of the young stellar cluster located in the vicinity of the IRAS 05137+3919 source, 84 PMS stellar objects were revealed. The age of the cluster is 1.5 - 2.0 million years. The PMS stars are not uniformly distributed in the cluster but form two subgroups. The first group is located near the YSO CPM 15, which is a binary object. The second one includes a significant amount of stars with early spectral types embedded in gas-dust nebulosity. The LF of the PMS stars allows to assume that the cluster is located at a distance of about 4.5 kpc. One of the components of the CPM 15 pair appears to have a spectral type of B3-B5 and is a Herbig Ae/Bestar.

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Unveiling the Surface Structure of Amorphous Solid Water via Selective Infrared Irradiation of OH Stretching Modes

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In the quest to understand the formation of the building blocks of life, amorphous solid water (ASW) is one of the
most widely studied molecular systems. Indeed, ASW is ubiquitous in the cold interstellar medium (ISM), where ASW-coated dust grains provide a catalytic surface for solid phase chemistry, and is believed to be present in the Earth’s atmosphere at high altitudes. It has been shown that the ice surface adsorbs small molecules such as CO, N$_2$, or CH$_4$, most likely at OH groups dangling from the surface. Our study presents completely new insights concerning the behaviour of ASW upon selective infrared (IR) irradiation of its dangling modes. When irradiated, these surface H$_2$O molecules reorganise, predominantly forming a stabilised monomer-like water mode on the ice surface. We show that we systematically provoke “hole-burning” effects (or net loss of oscillators) at the wavelength of irradiation and reproduce the same absorbed water monomer on the ASW surface. Our study suggests that all dangling modes share one common channel of vibrational relaxation; the ice remains amorphous but with a reduced range of binding sites, and thus an altered catalytic capacity.

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A Luminous Blue Variable Star Interacting with a Nearby Infrared Dark Cloud
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G79.29+0.46 is a nebula created by a Luminous Blue Variable (LBV) star candidate characterized by two almost circular concentric shells. In order to investigate whether the shells are interacting with the infrared dark cloud (IRDC) G79.3+0.3 located at the southwestern border of the inner shell, we conducted Jansky Very Large Array observations of NH$_3$(1,1), (2,2) and c-C$_3$H$_2$, and combined them with previous Effelsberg data. The overall NH$_3$ emission consists of one main clump, named G79A, elongated following the shape of the IRDC, plus two fainter and smaller cores to the north, which spatially match the inner infrared shell. We analysed the NH$_3$ spectra at each position with detected emission and inferred linewidth, rotational temperature, column density and abundance maps, and find that: i) the linewidth of NH$_3$(1,1) in the northern cores is 0.5 km/s, slightly larger than in their surroundings; ii) the NH$_3$ abundance is enhanced by almost one order of magnitude towards the northwestern side of G79A; iii) there is one ‘hot slab’ at the interface between the inner infrared shell and the NH$_3$ peak of G79A; iv) the western and southern edges of G79A present chemical differentiation, with c-C$_3$H$_2$ tracing more external layers than NH$_3$, similar to what is found in PDRs. Overall, the kinematics and physical conditions of G79A are consistent with both shock-induced and UV radiation-induced chemistry driven by the LBV star. Therefore, the IRDC is not likely associated with the star-forming region DR15, but located farther away, near G79.29+0.46 at 1.4 kpc.

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Fragmentation of massive dense cores down to $\sim 1000$ AU: Relation between fragmentation and density structure
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In order to shed light on the main physical processes controlling fragmentation of massive dense cores, we present a uniform study of the density structure of 19 massive dense cores, selected to be at similar evolutionary stages, for which their relative fragmentation level was assessed in a previous work. We inferred the density structure of the 19 cores through a simultaneous fit of the radial intensity profiles at 450 and 850 micron (or 1.2 mm in two cases) and the Spectral Energy Distribution, assuming spherical symmetry and that the density and temperature of the cores decrease with radius following power-laws. We find a weak (inverse) trend of fragmentation level and density power-law index, with steeper density profiles tending to show lower fragmentation, and vice versa. In addition, we find a trend of fragmentation increasing with density within a given radius, which arises from a combination of flat density profile and high central density and is consistent with Jeans fragmentation. We considered the effects of rotational-to-gravitational energy ratio, non-thermal velocity dispersion, and turbulence mode on the density structure of the cores, and found that compressive turbulence seems to yield higher central densities. Finally, a possible explanation for the origin of cores with concentrated density profiles, which are the cores showing no fragmentation, could be related with a strong magnetic field, consistent with the outcome of radiation magnetohydrodynamic simulations.

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Large-scale Asymmetries in the Transitional Disks of SAO 206462 and SR 21
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We present Atacama Large Millimeter/submillimeter Array (ALMA) observations in the dust continuum (690 GHz, 0.45 mm) and 12CO J = 6 − 5 spectral line emission, of the transitional disks surrounding the stars SAO 206462 and SR 21. These ALMA observations resolve the dust-depleted disk cavities and extended gaseous disks, revealing large-scale asymmetries in the dust emission of both disks. We modeled these disks structures with a ring and an azimuthal gaussian, where the azimuthal gaussian is motivated by the steady-state vortex solution from Lyra & Lin (2013). Compared to recent observations of HD 142527, Oph IRS 48, and LkHα 330, these are low-contrast (<2) asymmetries. Nevertheless, a ring alone is not a good fit, and the addition of a vortex prescription describes these data much better. The asymmetric component encompasses 15% and 28% of the total disk emission in SAO 206462 and SR 21, respectively, which corresponds to a lower limit of 2MJup of material within the asymmetry for both disks. Although the contrast in the dust asymmetry is low, we find that the turbulent velocity inside it must be large (~ 20% of the sound speed) in order to drive these azimuthally wide and radially narrow vortex-like structures. We obtain residuals from the ring and vortex fitting that are still significant, tracing non-axisymmetric emission in both disks. We compared these submillimeter observations with recently published H-band scattered light observations. For SR 21, the scattered light emission is distributed quite differently from submillimeter continuum emission, while for
SAO 206462, the submillimeter residuals are suggestive of spiral-like structure similar to the near-IR emission.

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The deuterium fractionation of water on solar-system scales in deeply-embedded low-mass protostars

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The water deuterium fractionation (HDO/H2O abundance ratio) has traditionally been used to infer the amount of water brought to Earth by comets. Measuring this ratio in deeply-embedded low-mass protostars makes it possible to probe the critical stage when water is transported from clouds to disks in which icy bodies are formed. We present sub-arcsecond resolution observations of HDO in combination with H218O from the PdBI toward the three low-mass protostars NGC 1333-IRAS 2A, IRAS 4A-NW, and IRAS 4B. The resulting HDO/H2O ratio is 7.4 ± 2.1 × 10^{-4} for IRAS 2A, 19.1 ± 5.4 × 10^{-4} for IRAS 4A-NW, and 5.9 ± 1.7 × 10^{-4} for IRAS 4B. Derived ratios agree with radiative transfer models within a factor of 2–4 depending on the source. Our HDO/H2O ratios for the inner regions (where T > 100 K) of four young protostars are only a factor of 2 higher than those found for pristine, solar system comets. These small differences suggest that little processing of water occurs between the deeply embedded stage and the formation of planetesimals and comets.

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Effects of stellar flybys on planetary systems: 3D modeling of the circumstellar disks damping effects

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Stellar flybys in star clusters are suspected to affect the orbital architecture of planetary systems causing eccentricity excitation and orbital misalignment between the planet orbit and the equatorial plane of the star. We explore whether the impulsive changes in the orbital elements of planets, caused by an hyperbolic stellar flyby, can be fully damped by the circumstellar disk surrounding the star. The time required to disperse stellar clusters is in fact comparable to circumstellar disk’s lifetime. We have modelled in 3D a system made of a solar type star surrounded by a low density disk with a giant planet embedded in it approached on a hyperbolic encounter trajectory by a second star, of similar mass and with its own disk. We focus on extreme configurations where a very deep stellar flyby perturbs a Jovian planet on an external orbit. This allows to test in full the ability of the disk to erase the effects of the stellar encounter. We find that the amount of mass lost by the disk during the stellar flyby is less than in 2D models where a single disk was considered due to the mass exchange between the two disks at the encounter. The damping in eccentricity is slightly faster than in 2D models and it occurs on timescales of the order of a few kyr. The only trace of the flyby left in the planet system, after about 10^4 yr, is a small misalignment, lower than 9°, between the star equatorial plane and the planet orbit. In a realistic model based on 3D simulations of star–planet–disk interactions, we find that stellar flybys cannot excite significant eccentricities and inclinations of planets in stellar clusters. The circumstellar disks hosting the planets damp on a short timescale all the step changes in the two orbital parameters produced during any stellar encounter. All records of past encounters are erased.

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Faint disks around classical T Tauri stars: Small but dense enough to form planets

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Context: Most Class II sources (of nearby star-forming regions) are surrounded by disks with weak millimeter continuum emission. These “faint” disks may hold clues to the disk dissipation mechanism. However, the physical properties of protoplanetary disks have been directly constrained by imaging only the brightest sources.

Aims: We attempt to determine the characteristics of such faint disks around classical T Tauri stars and to explore the link between disk faintness and the proposed disk dispersal mechanisms (accretion, viscous spreading, photo-evaporation, planetary system formation).

Methods: We performed high angular resolution (0.3′′) imaging of a small sample of disks (9 sources) with low 1.3 mm continuum flux (mostly < 30 mJy) with the IRAM Plateau de Bure interferometer and simultaneously searched for ¹³CO (or CO) J=2-1 line emission. Using a simple parametric disk model, we determined characteristic sizes of the disks in dust and gas, and we constrained surface densities in the central 50 AU.

Results: All disks are much smaller than the bright disks imaged so far, both in continuum and ¹³CO lines (5 detections). In continuum, half of the disks are very small, with characteristic radii less than 10 AU, but still have high surface density values. Small sizes appear to be the main cause of the low disk luminosity. Direct evidence for grain growth is found for the three disks that are sufficiently resolved. Low continuum opacity is attested in only two systems, but we cannot firmly distinguish between a low gas surface density and a lower dust emissivity resulting from grain growth. Finally, we report a tentative discovery of a ~ 20 AU radius cavity in DS Tau, which with the (unresolved) “transition” disk of CX Tau, brings the proportion of “transitional” disks to a similar value to that of brighter sources. The existence of cavities cannot by itself explain their observed low mm flux.

Conclusions: This study highlights a category of very compact dust disks that still exhibit high surface densities, which may represent up to 25% of the whole disk population. While its origin is unclear with the current data alone, it may be related to the compact planetary systems found by the Kepler mission.

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Millimetre spectral indices of transition disks and their relation with the cavity radius

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Context: Transition disks are protoplanetary disks with inner depleted dust cavities and excellent candidates to investigate the dust evolution under the existence of a pressure bump. A pressure bump at the outer edge of the cavity allows dust grains from the outer regions to stop their rapid inward migration towards the star and efficiently grow to millimetre sizes. Dynamical interactions with planet(s) have been one of the most exciting theories to explain the clearing of the inner disk.
Aims: We look for evidence of the presence of millimetre dust particles in transition disks by measuring their spectral index $\alpha_{mm}$ with new and available photometric data. We investigate the influence of the size of the dust depleted cavity on the disk integrated millimetre spectral index.

Methods: We present the 3-millimetre (100 GHz) photometric observations carried out with Plateau de Bure Interferometer of four transition disks: LkHα 330, UX Tau A, LRLL 31, and LRLL 67. We use available values of their fluxes at 345 GHz to calculate their spectral index, as well as the spectral index for a sample of twenty transition disks. We compare the observations with two kind of models. In the first set of models, we consider coagulation and fragmentation of dust in a disk in which a cavity is formed by a massive planet located at different positions. The second set of models assumes disks with truncated inner parts at different radius and with power-law dust size distributions, where the maximum size of grains is calculated considering turbulence as the source of destructive collisions.

Results: We show that the integrated spectral index is higher for transition disks (TD) than for regular protoplanetary disks (PD) with mean values of $\alpha_{mm}^{TD} = 2.70 \pm 0.13$ and $\alpha_{mm}^{PD} = 2.20 \pm 0.07$ respectively. For transition disks, the probability that the measured spectral index is positively correlated with the cavity radius is 95%. High angular resolution imaging of transition disks is needed to distinguish between the dust trapping scenario and the truncated disk case.

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Molecular ions in the protostellar shock L1157-B1

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Context: In this work, we perform a complete census of molecular ions with an abundance larger than $\sim 10^{-10}$ in the protostellar shock L1157-B1. This allows us to study the ionization structure and chemistry of the shock.

Methods: An unbiased high-sensitivity survey of L1157-B1 performed with the IRAM-30m and Herschel/HIFI as part of the CHESS and ASAI large programs allows searching for molecular ions emission. Then, by means of a radiative transfer code in the Large Velocity Gradient approximation, the gas physical conditions and fractional abundances of molecular ions are derived. The latter are compared with estimates of steady-state abundances in the cloud and their evolution in the shock calculated with the chemical model Astrochem.

Results: We detect emission from HCO$^+$, H$^{13}$CO$^+$, N$_2$H$^+$, HCS$^+$, and, for the first time in a shock, from HOCO$^+$, and SO$^+$. The bulk of the emission peaks at blueshifted velocity, $\sim 0.5 - 3$ km s$^{-1}$ with respect to systemic, has a width of $\sim 4 - 8$ km s$^{-1}$ and is associated with the outflow cavities ($T_{kin} \sim 20 - 70$ K, $n_{H2} \sim 10^5$ cm$^{-3}$). A high velocity component, up to $\sim 40$ km s$^{-1}$, associated with the primary jet is detected in the HCO$^+$ 1–0 line. Observed HCO$^+$ and N$_2$H$^+$ abundances ($X_{HCO^+} \sim 0.7 - 3 \times 10^{-8}$, $X_{N_2H^+} \sim 0.4 - 8 \times 10^{-9}$) are in agreement with steady-state abundances in the cloud and with their evolution in the compressed and heated gas in the shock for cosmic rays ionization rate $\zeta = 3 \times 10^{-16}$ s$^{-1}$. HOCO$^+$, SO$^+$, and HCS$^+$ observed abundances ($X_{HOCO^+} \sim 10^{-9}$, $X_{SO^+} \sim 8 \times 10^{-10}$, $X_{HCS^+} \sim 3 - 7 \times 10^{-10}$), instead, are 1–2 orders of magnitude larger than predicted in the cloud; on the other hand they are strongly enhanced on timescales shorter than the shock age ($\sim$2000 years) if CO$_2$, S or H$_2$S, and OCS are sputtered off the dust grains in the shock.

Conclusions: The performed analysis indicates that HCO$^+$ and N$_2$H$^+$ are a fossil record of pre-shock gas in the outflow cavity, while HOCO$^+$, SO$^+$, and HCS$^+$ are effective shock tracers and can be used to infer the amount of CO$_2$ and sulphur-bearing species released from dust mantles in the shock. The observed HCS$^+$ (and CS) abundance indicates that OCS should be one of the main sulphur carrier on grain mantles. However, the OCS abundance required to fit the observations is 1–2 orders of magnitude larger than observed. Laboratory experiments are required to measure the reactions rates involving these species and to fully understand the chemistry of sulphur-bearing species.

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Pre-main sequence stellar evolution in N-body models
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We provide a set of analytic fits to the radii of pre-main sequence stars in the mass range $0.1 < M/M_\odot < 8.0$. We incorporate the formulae in N-body cluster models for evolution from the beginning of pre-main sequence. In models with 1,000 stars and high initial cluster densities, pre-main sequence evolution causes roughly twice the number of collisions between stars than in similar models with evolution begun only from the zero-age main sequence. The collisions are often all part of a runaway sequence that creates one relatively massive star.

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G0.253+0.016: A centrally condensed, high-mass protocluster
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Despite their importance as stellar nurseries and the building blocks of galaxies, very little is known about the formation of the highest mass clusters. The dense clump G0.253+0.016 represents an example of a clump that may form an Arches-like, high-mass cluster. Here we present molecular line maps toward G0.253+0.016 taken as part of the MALT90 molecular line survey, complemented with APEX observations. Combined, these data reveal the global physical properties and kinematics of G0.253+0.016. Recent Herschel data show that while the dust temperature is low ($\sim 19$ K) toward its centre, the dust temperature on the exterior is higher ($\sim 27$ K) due to external heating. Our new molecular line data reveal that, overall, the morphology of dense gas detected toward G0.253+0.016 matches very well its IR extinction and dust continuum emission. An anti-correlation between the dust and gas column densities toward its centre indicates that the clump is centrally condensed with a cold, dense interior in which the molecular gas is chemically depleted. The velocity field shows a strong gradient along the clump’s major axis, with the blue-shifted side at higher Galactic longitude. The optically thick gas tracers are systematically red-shifted with respect to the optically thin and hot gas tracers, indicating radial motions. The gas kinematics and line ratios support the recently proposed scenario in which G0.253+0.016 results from a tidal compression during a recent pericentre passage near SgrA*. Because G0.253+0.016 represents an excellent example of a clump that may form a high-mass cluster, its detailed study should reveal a wealth of knowledge about the early stages of cluster formation.

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A sub-arcsecond study of the hot molecular core in G023.01-00.41
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(Abridged) Aims: We have selected a hot molecular core (HMC) in the high-mass star-forming region G023.01-00.41, where VLBI multi-epoch observations of water and methanol masers have suggested the existence of rotation and expansion within 2000 AU from its center. Our purpose is to image the thermal line and continuum emission at millimeter wavelengths to establish the physical parameters and velocity field of the gas in the region.

Methods: We performed SMA observations at 1.3 mm with both the most extended and compact array configurations, providing sub-arcsecond and high sensitivity maps of various molecular lines, including both hot-core and outflow tracers. We also reconstruct the spectral energy distribution of the region from millimeter to near infrared wavelengths, using the Herschel/Hi-GAL maps, as well as archival data.

Results: From the spectral energy distribution, we derive a bolometric luminosity of $\sim 4 \times 10^4 L_\odot$. Our interferometric observations reveal that the distribution of dense gas and dust in the HMC is significantly flattened and extends up to a radius of 8000 AU from the center of radio continuum and maser emission in the region. The equatorial plane of this HMC is strictly perpendicular to the elongation of the collimated bipolar outflow, as imaged on scales of $\sim 0.1$–0.5 pc in the main CO isotopomers as well as in the SiO(5–4) line. In the innermost HMC regions ($\sim 1000$ AU), the velocity field traced by the CH$_3$CN (12$K$ – 11$K$) line emission shows that molecular gas is both expanding along the outflow direction following a Hubble-law, and rotating about the outflow axis, in agreement with the (3-D) velocity field traced by methanol masers. The velocity field associated with rotation indicates a dynamical mass of $\sim 19 M_\odot$ at the center of the core. The latter is likely to be concentrated in a single O9.5 ZAMS star, consistent with the estimated bolometric luminosity of G023.01-00.41. The physical properties of the CO (2–1) outflow emission, such as its momentum rate $6 \times 10^{-3} M_\odot$ km s$^{-1}$ yr$^{-1}$ and its outflow rate $2 \times 10^{-4} M_\odot$ yr$^{-1}$, support our estimates of the luminosity (and mass) of the embedded young stellar object.

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Mining the VVV: star formation and embedded clusters

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The aim of this study is to locate previously unknown stellar clusters from the VISTA variables in the Vía Láctea Survey (VVV) catalogue data. The method, fitting a mixture model of Gaussian densities and background noise using the expectation maximization algorithm to a pre-filtered NIR survey stellar catalogue data, was developed by the authors for the UKIDSS Galactic Plane Survey (GPS). The search located 88 previously unknown mainly embedded stellar cluster candidates and 39 previously unknown sites of star formation in the 562 deg$^2$ covered by VVV in the Galactic bulge and the southern disk.

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Detecting scattered light from low-mass molecular cores at 3.6 $\mu$m - Impact of global effects on the observation of coreshine

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Recently discovered scattered light at 3–5 µm from low-mass cores (so-called "coreshine") reveals the presence of grains around 1 µm, which is larger than the grains found in the low-density interstellar medium. But only about half of the 100+ cores investigated so far show the effect. This prompts further studies on the origin of this detection rate. From the 3D continuum radiative transfer equation, we derive the expected scattered light intensity from a core placed in an arbitrary direction seen from Earth. We use the approximation of single scattering, consider extinction up to 2nd-order Taylor approximation, and neglect spatial gradients in the dust size distribution. The impact of the directional characteristics of the scattering on the detection of scattered light from cores is calculated for a given grain size distribution, and local effects like additional radiation field components are discussed. The surface brightness profiles of a core with a 1D density profile are calculated for various Galactic locations, and the results are compared to the approximate detection limits. We find that for optically thin radiation and a constant size distribution, a simple limit for detecting scattered light from a low-mass core can be derived that holds for grains with sizes smaller than 0.5 µm. The extinction by the core prohibits detection in bright parts of the Galactic plane, especially near the Galactic center. For scattered light received from low-mass cores with grain sizes beyond 0.5 µm, the directional characteristics of the scattering favors the detection of scattered light above and below the Galactic center, and to some extent near the Galactic anti-center. We identify the local incident radiation field as the major unknown causing deviations from this simple scheme.

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Water and methanol in low-mass protostellar outflows: gas-phase synthesis, ice sputtering and destruction

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Water in outflows from protostars originates either as a result of gas-phase synthesis from atomic oxygen at \( T \gtrsim 200 \) K, or from sputtered ice mantles containing water ice. We aim to quantify the contribution of the two mechanisms that lead to water in outflows, by comparing observations of gas-phase water to methanol (a grain surface product) towards three low-mass protostars in NGC1333. In doing so, we also quantify the amount of methanol destroyed in outflows. To do this, we make use of JCMT and Herschel-HIFI data of \( \text{H}_2\text{O}, \text{CH}_3\text{OH} \) and CO emission lines and compare them to RADEX non-LTE excitation simulations. We find up to one order of magnitude decrease in the column density ratio of \( \text{CH}_3\text{OH} \) over \( \text{H}_2\text{O} \) as the velocity increases in the line wings up to \( \sim 15 \text{ km s}^{-1} \). An independent decrease in \( X(\text{CH}_3\text{OH}) \) with respect to CO of up to one order of magnitude is also found in these objects. We conclude that gas-phase formation of \( \text{H}_2\text{O} \) must be active at high velocities (above \( 10 \text{ km s}^{-1} \) relative to the source velocity) to re-form the water destroyed during sputtering. In addition, the transition from sputtered water at low velocities to formed water at high velocities must be gradual. We place an upper limit of two orders of magnitude on the destruction of methanol by sputtering effects.

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The architecture of the LkCa 15 transitional disk revealed by high-contrast imaging

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We present four new epochs of $K_s$-band images of the young pre-transitional disk around LkCa 15, and perform extensive forward modeling to derive the physical parameters of the disk. We find indications of strongly anisotropic scattering ($g = 0.67^{+0.18}_{-0.11}$) and a significantly tapered gap edge (‘round wall’), but see no evidence that the inner disk, whose existence is predicted by the spectral energy distribution, shadows the outer regions of the disk visible in our images. We marginally confirm the existence of an offset between the disk center and the star along the line of nodes; however, the magnitude of this offset ($x = 27^{+19}_{-20}$ mas) is notably lower than that found in our earlier $H$-band images (Thalmann et al. 2010). Intriguingly, we also find, at high significance, an offset of $y = 69^{+49}_{-25}$ mas perpendicular to the line of nodes. If confirmed by future observations, this would imply a highly elliptical – or otherwise asymmetric – disk gap with an effective eccentricity of $e \approx 0.3$. Such asymmetry would most likely be the result of dynamical sculpting by one or more unseen planets in the system. Finally, we find that the bright arc of scattered light we see in direct imaging observations originates from the near side of the disk, and appears brighter than the far side because of strong forward scattering.

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Warm formaldehyde in the Oph IRS 48 transitional disk

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Simple molecules like H$_2$CO and CH$_3$OH in protoplanetary disks are the starting point for the production of more complex organic molecules. So far, the observed chemical complexity in disks has been limited due to freeze out of molecules onto grains in the bulk of the cold outer disk. Complex molecules can be studied more directly in transitional disks with large inner holes, as these have a higher potential of detection, through UV heating of the outer disk and the directly exposed midplane at the wall. We use Atacama Large Millimeter/submillimeter Array (ALMA) Band 9 ($\sim$680 GHz) line data of the transitional disk Oph IRS 48, previously shown to have a large dust trap, to search for complex molecules in regions where planetesimals are forming. We report the detection of the H$_2$CO 9(1,8)--8(1,7) line at 674 GHz, which is spatially resolved as a semi-ring at $\sim$60 AU radius centered south from the star. The inferred H$_2$CO abundance is $\sim$$10^{-8}$ derived by combining a physical disk model of the source with a non-LTE excitation calculation. Upper limits for CH$_3$OH lines in the same disk give an abundance ratio H$_2$CO/CH$_3$OH>$0.3$, which points to both ice formation and gas-phase routes playing a role in the H$_2$CO production. Upper limits on the abundances of H$^{13}$CO+, CN and several other molecules in the disk are also derived and found to be consistent with full chemical models. The detection of the H$_2$CO line demonstrates the start of complex organic molecules in a planet-forming disk. Future
ALMA observations should be able to push down the abundance detection limits of other molecules by 1–2 orders of magnitude and test chemical models of organic molecules in (transitional) disks.

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High-resolution ammonia mapping of the very young protostellar core Chamaeleon-MMS1

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The aim of this study is to investigate the structure and kinematics of the nearby candidate first hydrostatic core Cha-MMS1.

Cha-MMS1 was mapped in the NH₃(1,1) line and the 1.2 cm continuum using the Australia Telescope Compact Array, ATCA. The angular resolution of the ATCA observations is 7″ (~1000 AU), and the velocity resolution is 50 m s⁻¹. The core was also mapped with the 64-m Parkes telescope in the NH₃(1,1) and (2,2) lines. Observations from Herschel Space Observatory and Spitzer Space telescope were used to help interpretation. The ammonia spectra were analysed using Gaussian fits to the hyperfine structure. A two-layer model was applied in the central parts of the core where the ATCA spectra show signs of self-absorption.

A compact high column density core with a steep velocity gradient (~20 km s⁻¹ pc⁻¹) is detected in ammonia. We derive a high gas density (~10⁶ cm⁻³) in this region, and a fractional ammonia abundance compatible with determinations towards other dense cores (~10⁻⁸). This suggests that the age of the high density core is comparable to the freeze-out timescale of ammonia in these conditions, of the order of 10⁴ years. The direction of the velocity gradient agrees with previous single-dish observations, and the overall velocity distribution can be interpreted as rotation. The rotation axis goes through the position of a compact far-infrared source detected by Spitzer and Herschel. The specific angular momentum of the core, ~10⁻³ km s⁻¹ pc, is typical for protostellar envelopes. A string of 1.2 cm continuum sources is tentatively detected near the rotation axis. The ammonia spectra suggest the presence of warm embedded gas in its vicinity. An hourglass-shaped structure is seen in ammonia at the cloud’s average LSR velocity, also aligned with the rotation axis. Although this structure resembles a pair of outflow lobes the ammonia spectra show no indications of shocked gas.

The observed ammonia structure mainly delineates the inner envelope around the central source. The velocity gradient is likely to originate in the angular momentum of the contracting core, although influence of the outflow from the neighbouring young star IRS4 is possibly visible on one side of the core. The tentative continuum detection and the indications of a warm background component near the rotation axis suggest that the core contains a deeply embedded outflow which may have been missed in previous single-dish CO surveys owing to beam dilution.

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Feasibility of transit photometry of nearby debris discs

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Dust in debris discs is constantly replenished by collisions between larger objects. In this paper, we investigate a method to detect these collisions. We generate models based on recent results on the Fomalhaut debris disc, where we simulate a background star transiting behind the disc, due to the proper motion of Fomalhaut. By simulating the expanding dust clouds caused by the collisions in the debris disc, we investigate whether it is possible to observe changes in the brightness of the background star. We conclude that in the case of the Fomalhaut debris disc, changes in the optical depth can be observed, with values of the optical depth ranging from $10^{-0.5}$ for the densest dust clouds to $10^{-8}$ for the most diffuse clouds with respect to the background optical depth of $\sim 1.2 \times 10^{-3}$.

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350 $\mu$m map of the Ophiuchus molecular cloud: core mass function

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Stars are born in dense cores of molecular clouds. The core mass function (CMF), which is the mass distribution of dense cores, is important for understanding the stellar initial mass function (IMF). We obtained 350 $\mu$m dust continuum data using the SHARC-II camera at the Caltech Submillimeter Observatory (CSO) telescope. A 350 $\mu$m map covering 0.25 $\text{deg}^2$ of the Ophiuchus molecular cloud was created by mosaicing 56 separate scans. The CSO telescope had an angular resolution of 9$''$, corresponding to $1.2 \times 10^3$ AU at the distance of the Ophiuchus molecular cloud (131 pc). The data was reduced using the Comprehensive Reduction Utility for SHARC-II (CRUSH). The flux density map was analyzed using the GaussClumps algorithm, within which 75 cores has been identified. We used the Spitzer c2d catalogs to separate the cores into 63 starless cores and 12 protostellar cores. By locating Jeans instabilities, 55 prestellar cores (a subcategory of starless cores) were also identified. The excitation temperatures, which were derived from FCRAO $^{12}$CO data, help to improve the accuracy of the masses of the cores. We adopted a Monte Carlo approach to analyze the CMF with two types of functional forms; power law and log-normal. The whole and prestellar CMF are both well fitted by a log-normal distribution, with $\mu = -1.18 \pm 0.10$, $\sigma = 0.58 \pm 0.05$ and $\mu = 1.40 \pm 0.10$, $\sigma = 0.50 \pm 0.05$ respectively. This finding suggests that turbulence influences the evolution of the Ophiuchus molecular cloud.

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Accretion onto Planetary Mass Companions of Low-Mass Young Stars

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Measurements of accretion rates onto planetary mass objects may distinguish between different planet formation mechanisms, which predict different accretion histories. In this Letter, we use $HST$/WFC3 UVIS optical photometry to measure accretion rates onto three accreting objects, GSC06214-00210 b, GQ Lup b, and DH Tau b, that are at the
planet/brown dwarf boundary and are companions to solar mass stars. The excess optical emission in the H Balmer and H Paschen continuum yields mass accretion rates of $10^{-9}$ to $10^{-11} M_\odot/yr$ for these three objects, which are an order of magnitude higher than expected from the correlation between planetary mass objects formed by protostellar core fragmentation. The high accretion rates and large separation demonstrate the presence of massive disks around these objects. Formation and evolution models for wide planetary mass companions should account for their large accretion rates. High ratios of H$\alpha$ luminosity over accretion luminosity for objects with low accretion rates suggests that searches for H$\alpha$ emission may be an efficient way to find accreting planets.

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Particle Concentration At Planet Induced Gap Edges and Vortices: I. Inviscid 3-D Hydro Disks

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We perform a systematic study of the dynamics of dust particles in protoplanetary disks with embedded planets using global 2-D and 3-D inviscid hydrodynamic simulations. Lagrangian particles have been implemented into magnetohydrodynamic code Athena with cylindrical coordinates. We find two distinct outcomes depending on the mass of the embedded planet. In the presence of a low mass planet ($<8 M_\oplus$), two narrow gaps start to open in the gas on each side of the planet where the density waves shock. These shallow gaps can dramatically affect particle drift speed and cause significant, roughly axisymmetric dust depletion. On the other hand, a more massive planet ($>0.1 M_J$) carves out a deeper gap with sharp edges, which are unstable to the vortex formation. Particles with a wide range of sizes ($0.02 < \Omega_t s < 20$) are trapped and settle to the midplane in the vortex, with the strongest concentration for particles with $\Omega_t s \sim 1$. The dust concentration is highly elongated in the $\phi$ direction, and can be as wide as 4 disk scale heights in the radial direction. Dust surface density inside the vortex can be increased by more than a factor of $10^2$ in a very non-axisymmetric fashion. For very big particles ($\Omega_t s \gg 1$) we find strong eccentricity excitation, in particular around the planet and in the vicinity of the mean motion resonances, facilitating gap opening there. Our results imply that in weakly turbulent protoplanetary disk regions (e.g. the “dead zone”) dust particles with a very wide range of sizes can be trapped at gap edges and inside vortices induced by planets with $M_p < M_J$, potentially accelerating planetesimal and planet formation there, and giving rise to distinctive features that can be probed by ALMA and EVLA.

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Interplay of Chemistry and Dynamics in the Low-Mass Star Formation
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Molecular clouds are a very unique chemical laboratory. Due to the low gas density, the collisional time scale among gas particles is as long as a few days, so that radicals and ion molecules, which would be promptly destroyed by reactions in laboratories on Earth, can be abundant. Molecular clouds are important for astrophysics as well, since they are the formation site of stars and planets. In this paper we mainly consider the region of low-mass stars formation, where Sun-like stars are formed. The cores start collapse to form stars, once the gravity overwhelms the pressure gradient. Detailed structures of cores are observed to study star formation processes. As a core collapses, the rotational velocity increases due to the angular momentum conservation. Eventually, the centrifugal force balances the gravitational force, and a 100 AU-size disk is formed. Planetary systems are formed in the circumstellar disks. The evolutionary sequence from molecular clouds to planetary systems, and the detection of various molecular lines in each evolutionary stage, naturally give rise to many questions. How are the molecules in molecular clouds and cloud cores incorporated to protoplanetary disks? How is the chemical composition altered during the star- and planet formation processes? What is the major carrier of volatile elements in disks, and how do they vary as a function of time and distance from the central star? Combinations of hydrochemical models and observation of star-forming cores and disks are powerful tools to tackle these questions. We will review chemistry in earlier stages, from molecular cloud cores to forming protoplanetary disks.

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Planet Population Synthesis
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With the increasing number of exoplanets discovered, statistical properties of the population as a whole become unique constraints on planet formation models provided a link between the description of the detailed processes playing a role in this formation and the observed population can be established. Planet population synthesis provides such a link. The approach allows to study how different physical models of individual processes (e.g., proto-planetary disc structure and evolution, planetesimal formation, gas accretion, migration, etc.) affect the overall properties of the population of emerging planets. By necessity, planet population synthesis relies on simplified descriptions of complex processes. These descriptions can be obtained from more detailed specialised simulations of these processes. The objective of this chapter is twofold: 1) provide an overview of the physics entering in the two main approaches to planet population synthesis and 2) present some of the results achieved as well as illustrate how it can be used to extract constraints on the models and to help interpret observations.

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An Observational Perspective of Transitional Disks

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Transitional disks are objects whose inner disk regions have undergone substantial clearing. The Spitzer Space Telescope produced detailed spectral energy distributions (SEDs) of transitional disks that allowed us to infer their radial dust disk structure in some detail, revealing the diversity of this class of disks. The growing sample of transitional disks also opened up the possibility of demographic studies, which provided unique insights. There now exist (sub)millimeter and infrared images that confirm the presence of large clearings of dust in transitional disks. In addition, protoplanet candidates have been detected within some of these clearings. Transitional disks are thought to be a strong link to planet formation around young stars and are a key area to study if further progress is to be made on understanding the initial stages of planet formation. Here we provide a review and synthesis of transitional disk observations to date with the aim of providing timely direction to the field, which is about to undergo its next burst of growth as ALMA reaches its full potential. We discuss what we have learned about transitional disks from SEDs, color-color diagrams, and imaging in the (sub)mm and infrared. We note the limitations of these techniques, particularly with respect to the sizes of the clearings currently detectable, and highlight the need for pairing broad-band SEDs with multi-wavelength images to paint a more detailed picture of transitional disk structure. We review the gas in transitional disks, keeping in mind that future observations with ALMA will give us unprecedented access to gas in disks, and also observed infrared variability pointing to variable transitional disk structure, which may have implications for disks in general. We then distill the observations into constraints for the main disk clearing mechanisms proposed to date (i.e., photoevaporation, grain growth, and companions) and explore how the expected observational signatures from these mechanisms, particularly planet-induced disk clearing, compare to actual observations. Lastly, we discuss future avenues of inquiry to be pursued with ALMA, JWST, and next generation of ground-based telescopes.

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http://www.mpia-hd.mpg.de/homes/ppvi/chapter/espaillat.pdf
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The multifaceted planetesimal formation process

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Accumulation of dust and ice particles into planetesimals is an important step in the planet formation process. Planetesimals are the seeds of both terrestrial planets and the solid cores of gas and ice giants forming by core
accretion. Left-over planetesimals in the form of asteroids, trans-Neptunian objects and comets provide a unique record of the physical conditions in the solar nebula. Debris from planetesimal collisions around other stars signposts that the planetesimal formation process, and hence planet formation, is ubiquitous in the Galaxy. The planetesimal formation stage extends from micrometer-sized dust and ice to bodies which can undergo run-away accretion. The latter ranges in size from 1 km to 1000 km, dependent on the planetesimal eccentricity excited by turbulent gas density fluctuations. Particles face many barriers during this growth, arising mainly from inefficient sticking, fragmentation and radial drift. Two promising growth pathways are mass transfer, where small aggregates transfer up to 50% of their mass in high-speed collisions with much larger targets, and fluffy growth, where aggregate cross sections and sticking probabilities are enhanced by a low internal density. A wide range of particle sizes, from mm to 10 m, concentrate in the turbulent gas flow. Overdense filaments fragment gravitationally into bound particle clumps, with most mass entering planetesimals of contracted radii from 100 to 500 km, depending on local disc properties. We propose a hybrid model for planetesimal formation where particle growth starts unaided by self-gravity but later proceeds inside gravitationally collapsing pebble clumps to form planetesimals with a wide range of sizes.

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The Big Problems in Star Formation: the Star Formation Rate, Stellar Clustering, and the Initial Mass Function

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Star formation lies at the center of a web of processes that drive cosmic evolution: generation of radiant energy, synthesis of elements, formation of planets, and development of life. Decades of observations have yielded a variety of empirical rules about how it operates, but at present we have no comprehensive, quantitative theory. In this review I discuss the current state of the field of star formation, focusing on three central questions: what controls the rate at which gas in a galaxy converts to stars? What determines how those stars are clustered, and what fraction of the stellar population ends up in gravitationally-bound structures? What determines the stellar initial mass function, and does it vary with star-forming environment? I use these three question as a lens to introduce the basics of star formation, beginning with a review of the observational phenomenology and the basic physical processes. I then review the status of current theories that attempt to solve each of the three problems, pointing out links between them and opportunities for theoretical and numerical work that crosses the scale between them. I conclude with a discussion of prospects for theoretical progress in the coming years.

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Exoplanetary Atmospheres

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The study of exoplanetary atmospheres is one of the most exciting and dynamic frontiers in astronomy. Over the past two decades ongoing surveys have revealed an astonishing diversity in the planetary masses, radii, temperatures, orbital parameters, and host stellar properties of exoplanetary systems. We are now moving into an era where we can begin to address fundamental questions concerning the diversity of exoplanetary compositions, atmospheric and
interior processes, and formation histories, just as have been pursued for solar system planets over the past century. Exoplanetary atmospheres provide a direct means to address these questions via their observable spectral signatures. In the last decade, and particularly in the last five years, tremendous progress has been made in detecting atmospheric signatures of exoplanets through photometric and spectroscopic methods using a variety of space-borne and/or ground-based observational facilities. These observations are beginning to provide important constraints on a wide gamut of atmospheric properties, including pressure-temperature profiles, chemical compositions, energy circulation, presence of clouds, and non-equilibrium processes. The latest studies are also beginning to connect the inferred chemical compositions to exoplanetary formation conditions. In the present chapter, we review the most recent developments in the area of exoplanetary atmospheres. Our review covers advances in both observations and theory of exoplanetary atmospheres, and spans a broad range of exoplanet types (gas giants, ice giants, and super-Earths) and detection methods (transiting planets, direct imaging, and radial velocity). We close with a discussion of the bright prospects for future studies of exoplanetary atmospheres. Accepted by PPVI

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The Milky Way as a Star Formation Engine

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The cycling of material from the interstellar medium (ISM) into stars and the return of stellar ejecta into the ISM is the engine that drives the “galactic ecology” in normal spirals, a cornerstone in the formation and evolution of galaxies through cosmic time. Major observational and theoretical challenges need to be addressed in determining the processes responsible for converting the low-density ISM into dense molecular clouds, forming dense filaments and clumps, fragmenting them into stars, OB associations and bound clusters, and characterizing the feedback that limits the rate and efficiency of star formation. This formidable task can be now effectively attacked thanks to the combination of new global-scale surveys of the Milky Way Galactic Plane from infrared to radio wavelengths, offering the possibility of bridging the gap between local and extragalactic star formation studies. The Herschel, Spitzer and WISE mid to far infrared continuum surveys, complemented by analogue surveys from ground-based facilities in the millimetre and radio wavelengths, enables us to measure the Galactic distribution and physical properties of dust on all scales and in all components of the ISM from diffuse clouds to filamentary complexes and tens of thousands of dense clumps. A complementary suite of spectroscopic surveys in various atomic and molecular tracers is providing the
chemical fingerprinting of dense clumps and filaments, as well as essential kinematic information to derive distances and thus transform panoramic data into a 3D representation. The latest results emerging from these Galaxy-scale surveys are reviewed. New insights into cloud formation and evolution, filaments and their relationship to channeling gas onto gravitationally-bound clumps, the properties of these clumps, density thresholds for gravitational collapse, and star and cluster formation rates are discussed.

http://arxiv.org/pdf/1402.6196

Multiplicity in Early Stellar Evolution

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Observations from optical to centimeter wavelengths have demonstrated that multiple systems of two or more bodies is the norm at all stellar evolutionary stages. Multiple systems are widely agreed to result from the collapse and fragmentation of cloud cores, despite the inhibiting influence of magnetic fields. Surveys of Class 0 protostars with mm interferometers have revealed a very high multiplicity frequency of about 2/3, even though there are observational difficulties in resolving close protobinaries, thus supporting the possibility that all stars could be born in multiple systems. Near-infrared adaptive optics observations of Class I protostars show a lower binary frequency relative to the Class 0 phase, a declining trend that continues through the Class II/III stages to the field population. This loss of companions is a natural consequence of dynamical interplay in small multiple systems, leading to ejection of members. We discuss observational consequences of this dynamical evolution, and its influence on circumstellar disks, and we review the evolution of circumbinary disks and their role in defining binary mass ratios. Special attention is paid to eclipsing PMS binaries, which allow for observational tests of evolutionary models of early stellar evolution. Many stars are born in clusters and small groups, and we discuss how interactions in dense stellar environments can significantly alter the distribution of binary separations through dissolution of wider binaries. The binaries and multiples we find in the field are the survivors of these internal and external destructive processes, and we provide a detailed overview of the multiplicity statistics of the field, which form a boundary condition for all models of binary evolution. Finally we discuss various formation mechanisms for massive binaries, and the properties of massive trapezia.

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http://arxiv.org/pdf/1403.1907
This thesis presents the results of several projects where we used astrometry, at radio frequencies, to help characterize young stellar objects (YSOs). The results can be divided into three parts. First, we used archive and new VLA (Very Large Array) observations to measure proper motions for different targets in HH 124 IRS, W3(OH), Cyg OB2 and DG Tau A-B. Second, we used the VLBA (Very Long Baseline Array) to measure trigonometrical parallaxes to compact objects in the Cep A, Serpens and Cyg OB2 star forming regions. The measured distances to Cep A and Cyg OB2 are in good agreement with recent measured values using the same technique. The distance to Serpens, on the other hand, was significantly larger than the most recently used values, that were obtained using different methods. We propose that our measured distance is closer to the true distance for the Serpens core and that the other shortest values can reflect contamination from nearest clouds toward the Aquila Rift. Finally, we started a VLA survey of YSOs to characterize their radio emission, particularly we are interested in the non-thermal YSOs (gyrosynchrotron emitters) which we are planning to observe with the VLBA and measure their trigonometrical parallax in the future. In the thesis, the results for the Ophiuchus, Taurus, HH 124 IRS and B59 star forming regions are presented.
This thesis is devoted to a study of the conditions and evolution of the planet formation region in young circumstellar disks, by means of spectroscopic observations of molecular gas emission. The main focus of this work is the infrared spectrum of water (H$_2$O), which provides thousands of emission lines tracing the warm and dense gas inward of the water snow line in disks. The analysis includes also emission from some organic molecules that trace the carbon chemistry, C$_2$H$_2$, HCN, and CO$_2$, as well as emission from OH that is connected to the formation and destruction of the water molecule.

Two are the main directions explored in this work, for which we used spectra from the Spitzer Space Telescope (IRS) and the Very Large Telescope (VISIR and X-shooter). The first is to investigate how variable accretion phenomena occurring during the T Tauri phase affect the molecular environments in the planet formation region of disks. By monitoring T Tauri stars in different phases of accretion, we found that outbursts can remarkably affect their mid-infrared molecular emission. We propose a scenario where accretion flares trigger a recession of the water snow line, increasing water emission from the disk, when the accretion luminosity keeps higher over long enough timescales for the thermal structure of the disk to change (at least a few weeks, as observed in the strongly variable EX Lupi). In addition, enhanced UV radiation is found to produce OH from photodissociation of water in the disk. Organic molecules instead disappear during a strong outburst, and we are currently investigating the long-term evolution of these effects.

A second direction was taken to tackle another fundamental problem: the origin of water vapor in inner disks. Some models predict that water is produced by evaporation of icy solids migrating inward of the snow line. One way to probe this scenario is by measuring the abundance of water vapor in the inner disk, and compare it to the oxygen abundance available to form water in situ. In this thesis, for the first time, a systematic rotation diagram analysis has been applied to infrared water emission. This analysis established a link between the spread of the rotational scatter and the water abundance in the inner disk, where a large rotational scatter would provide evidence for the migration scenario. Large rotational scatters are indeed observed in some disks, supporting water vapor enrichment from evaporation of icy migrators. Future higher-resolution observations will provide important answers on the origin of water vapor and its connection to disk evolution and planet formation processes.

Electronic/printed copies of this PhD thesis are available upon request to the author.
The evolution of massive clumps in star forming regions

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Ph.D dissertation directed by: J. Brand
Ph.D degree awarded: February 2014

In this thesis two related topics are addressed:

• The first stages of the process of massive star formation, investigating the physical conditions and properties of massive clumps in different evolutionary stages, and their CO depletion;

• The influence that high-mass stars have on the nearby material and on the activity of star formation.

I derive the gas and dust temperature, mass and density of a sample of massive clumps, and analyse the variation in time of these properties from quiescent clumps, without any sign of active star formation, to clumps likely hosting a zero-age main sequence star. More evolved sources appear to be hotter, denser, more centrally concentrated and with a steeper radial density gradient of H\(_2\). I briefly discuss CO depletion and recent observations of several molecular species, tracers of Hot Cores and/or shocked gas, in a subsample of these clumps. The issue of CO depletion is addressed in more detail in a larger sample consisting of the brightest sources in the ATLASGAL survey. Using a radiative transfer code I investigate how the depletion changes from IR-dark clouds to more evolved objects, and compare this to what happens in the low-mass regime. CO depletion is found to be substantial (up to \(\sim 20\)), to decrease with time and to depend on the temperature and density of the gas. I estimate the radius of the central depletion zone to be typically a few tenths of a pc.

Regarding the second topic of the thesis, I derive the physical properties of the molecular gas in the photon-dominated region adjacent to the H\(_\text{ii}\) region G353.2+0.9 in the vicinity of Pismis 24, a young cluster, containing some of the most massive and hottest stars known in our Galaxy. The gas is found to be hotter and denser near the main ionisation front. In this region, molecular abundances are a factor of 2 – 3 lower than further away from the cluster. Pismis 24 is found to have an age of 1 – 3 Myr and its IMF is consistent with those proposed by Kroupa et al. (1993) and Scalo (1998). The cluster is likely supervirial, and the star formation efficiency connected with its formation is estimated to be \(\sim (2 – 15\%)\).

Much of the data analysis is done with a Bayesian approach. Therefore, a separate chapter is dedicated to the concepts of Bayesian statistics.

http://www.ira.inaf.it/Library/phd/giannetti-phd.pdf
Four postdoctoral fellowships are available to work in the application of interferometry to star formation at the Dublin Institute for Advanced Studies.

Areas of interest

Four postdoctoral fellowships are available to work in the application of interferometry to star formation at the Dublin Institute for Advanced Studies. Two fellows will collaborate with the Max Planck Institute of Astronomy in Heidelberg to assist with the development and commissioning of the next generation interferometer GRAVITY on the VLT. The other two fellows will work closely with Tautenburg Observatory, near Jena, in the use of LOFAR long baseline data to help understand the generation of outflows from young stars. All positions are for two years in the first instance but may be extended depending on external funding. Appointments will be at the Science Foundation Ireland New Postdoctoral Researcher or Experienced Postdoctoral Researcher level.

Further information on the posts can be obtained at http://www.dias.ie/index.php?option=com_content&view=article&id=4043&Itemid=61&lang=en including details of the salary scales.

Applications, to include a CV, Statement of Research Interests and the names and contact details of 3 individuals from whom letters of recommendation may be sought, are to be emailed to Eileen Flood (eflood@cp.dias.ie).

Informal inquiries to Head of the Star Formation Group, Professor Tom Ray (tr@cp.dias.ie).

Lectureship, University of Kent, Canterbury

The Centre for Astrophysics & Planetary Science at the University of Kent, Canterbury, U.K., expects to appoint at least one Lecturer within the School of Physical Sciences. The purpose of this role is to conduct research of an internationally competitive standard and to provide physics teaching, including Astrophysics, Space Science and Astronomy, to both undergraduate and postgraduate students within the School. The Centre has particular interests in star formation, galactic astronomy, space and solar system science. The closing date for applications is 6 April, 2014. See http://astro.kent.ac.uk for further details.
Meetings

AASTCS 4: Workshop on Dense Cores: Origin, Evolution, and Collapse
27-30 July 2014 – Monterey, CA, USA

Dense cores are the molecular cloud structures that spawn low-mass stars, and perhaps massive stars as well. Given their pivotal role, many in the star formation community have devoted considerable energy to studying them, both observationally and theoretically. This three-day meeting will bring together researchers working at the forefront of this exciting area. We envision an informal and highly interactive workshop, with much time devoted to lively group discussion and daily poster sessions. We urge interested colleagues to register and submit an abstract for a contributed talk or a poster.

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http://ism2014.strw.leidenuniv.nl

Habitable Worlds Across Time and Space
28 April - 1 May 2014 Baltimore, USA
http://www.stsci.edu/institute/conference/habitable-worlds

The Formation of the Solar System
13 - 15 May 2014 MPIfR, Bonn, Germany
https://indico.mpifr-bonn.mpg.de/theFormationOfTheSolarSystem

The Olympian Symposium on Star Formation
26 - 30 May 2014 Paralia Katerini’s, Mount Olympus, Greece
http://zuserver2.star.ucl.ac.uk/~ossf14/

EPoS2014 The Early Phase of Star Formation
1 - 6 June 2014 Ringberg Castle, Tegernsee, Germany

The Dance of Stars: Dense Stellar Systems from Infant to Old
2 - 6 June 2014 Bad Honnef, Germany
http://www.astro.uni-bonn.de/\$\sim sambaran/DS2014/index.html

The 18th Cambridge Workshop on Cool Stars, Stellar Systems and the Sun
9 - 13 June 2014 Flagstaff, Arizona, USA
http://www2.lowell.edu/workshops/coolstars18/

Summer School on Protoplanetary Disks: Theory and Modeling meet Observations
16 - 20 June 2014 Groningen, The Netherlands
http://www.diana-project.com/summer-school

Characterizing Planetary Systems Across the HR Diagram
28 July - 1 August 2014 Inst. for Astronomy, Cambridge, USA
http://www.ast.cam.ac.uk/meetings/2013/AcrossHR

Planet Formation and Evolution 2014
8 - 10 September 2014 Kiel, Germany
http://www.astrophysik.uni-kiel.de/kiel2014

Living Together: Planets, Stellar Binaries and Stars with Planets
8 - 12 September 2014 Litomysl Castle, Litomysl, Czech Republic

Galactic and Extragalactic Star Formation
8 - 12 September 2014 Marseille, France

Thirty Years of Beta Pic and Debris Disk Studies
8 - 12 September 2013 Paris, France
http://betapic30.sciencesconf.org
Short Announcements

All 38 chapters for Protostars and Planets VI are now done with the refereeing process and accepted for the book. While the book is being prepared for publication in the fall of this year, the preliminary chapters are linked to our homepage. You can find them at http://www.mpia-hd.mpg.de/homes/ppvi/prognew.php and there always click on the "chapter" link.

Kind regards

The PPVI Editorial Team
This book provides a comprehensive and up-to-date account of the formation of the solar system, written at a level so it is accessible to a scientifically literate general reader. The book focuses on the science of the subject, rather than the scientists behind the discoveries, providing a reconnaissance of the facts, models, and theories underlying our present-day understanding of the formation and evolution of the solar system. The author team is eminently qualified for the task, one is a well known planetary scientist and the other an experienced science writer. The result of their efforts is a highly readable book.

The following lists the chapters of the book:

1 Cosmic Archaeology
2 Discovering the Solar System
3 An Evolving Solar System
4 The Question of Timing
5 Meteorites
6 Cosmic Chemistry
7 A Star is Born
8 Nursery for Planets
9 World of Rock and Metal
10 The Making of the Moon
11 Earth, Cradle of Life
12 Worlds of Gas and Ice
13 What happened to the Asteroid Belt?
14 The Outermost Solar System
15 Epilogue: Paradigms, Problems, and Predictions

299 pages, hardcover US$29.95
Also available as an ebook