THE STAR FORMATION NEWSLETTER

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

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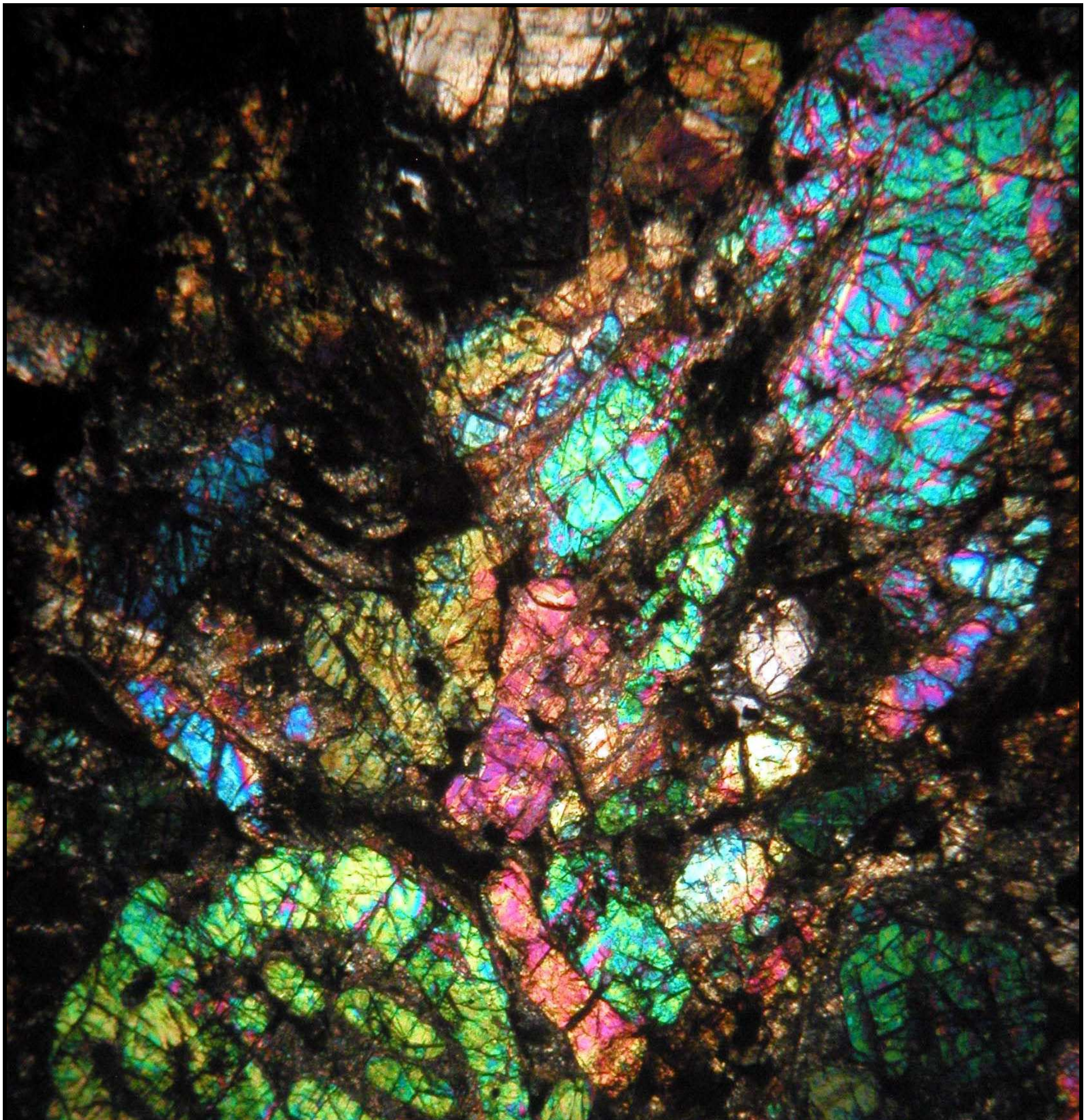

The Star Formation Newsletter

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

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Cover Picture

The image shows a photo of a thin slice of the Knyahinya meteorite, which was observed to fall on June 9, 1866 in Ukraine. It is classified as L/LL5, meaning an ordinary chondrite from either the L group or LL group that is petrologic type 5. L and LL stand for the low-iron chemical group of ordinary chondrites. Some 1200 stones fell in a ∼7 by 4 km strewn field and produced about half a ton of recovered meteorites. The largest stone, which broke into three pieces on impact, weighed 279 kg.

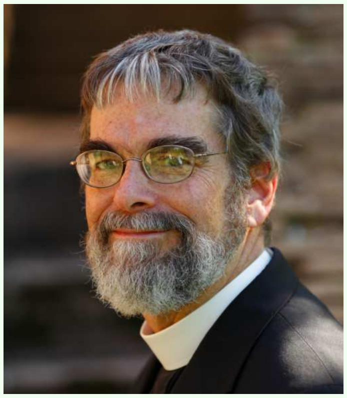
Photo courtesy Guy Consolmagno, of specimen from the Specola Vaticana collection.

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

Guy Consolmagno

in conversation with Bo Reipurth



Q: *You are the curator of the Meteorite Collection at the Vatican Observatory. What are your responsibilities?*

A: I have two different tasks with the collection. As curator I have to keep track of the more than one thousand samples and as anyone who's seen Night at the Museum knows, those pieces get up and move in the night when no one is looking! So I maintain the database, photographing each sample, and every couple of years I do a complete inventory to see if we've mislaid any pieces.

More regularly, I also am in charge of deciding to allow samples to be used by other scientists, and preparing samples so that they can be used. For example, over the past year nearly fifty papers have been written that have taken data on the extremely rare Martian meteorite, Chassigny; more than half of those papers are based on thin sections that we have prepared and loaned out from the Vatican collection.

The fact is, I am a scientist first, and a curator second. That's not typical of most meteorite collections, where the person in charge is often called the "keeper," not the curator – and for good reason! But I think that these samples are useless if they are not being used. The important decision is to make sure that they are used sensibly, and that proper care is taken to be sure that the material is not unnecessarily consumed or damaged.

Which brings up my other task: to actually use the materials myself for research.

Q: *What kind of research takes place with the Collection?*

A: The core of our collection started out as a collector's collection, the private collection of the Marquis de Mauroy, a 19th-century French nobleman. He donated some of them to the Vatican around 1905, while the remainder were donated by his widow in 1935. That means we have a lot of small pieces, and something of nearly everything, but not a whole lot of any particular type of meteorite. And the pieces are mostly well over 100 years old; they've been handled by who knows how many people, these aren't the sorts of pieces you'd use to search for traces of extraterrestrial organics!

Furthermore, we're a small lab. We don't have the resources to invest in a scanning electronic microscope, mass spectrometer, or any of the other amazing tools that are now available to analyze a tiny bit of meteorite, atom by atom. Nor do we have the staff needed to keep such equipment running! The fact is, that sort of chemical analysis is already being done in labs far better suited for it than ours.

What we do have, however, is a situation where as a member of the Vatican Observatory I don't have to worry about funding from year to year. That means I have the freedom to do large scale non-destructive survey measurements of physical properties that might take a decade to complete. It's the sort of work that's really important for the field but which most researchers can't engage in if they're worried about tenure or grant renewals.

Q: *Is outreach an important component of your work?*

A: Of course. The reason that the Vatican supports an astronomical observatory is to show the world that the Church supports science. So an essential part of our work is the "showing" part. Nowadays, unfortunately, that mostly means reminding the ultra-religious that being anti-science is actually contrary to the traditions and teaching of our religion. Logic, reason, and science were invented in the medieval universities, founded by the church; the way we study the unknown follows the rules of logic invented by scholastic theologians.

Q: *You have been to Antarctica to search for meteorites. How was that experience?*

A: It was the fulfillment of a childhood dream. I grew up in Michigan, loving the cold winters, and often played at "exploring the south pole" in my snow-covered back yard. I never expected to be able to do it for real.

Antarctica was the closest I have ever been, or ever will be, to walking on another planet. As a recent ANSMET team member, Don Pettit, has put it, If youve done ANSMET, youve done long duration space flight. He should know; he's a three-time Space Shuttle and International Space Station crew member.

The ANSMET program – Antarctic Search for Meteorites – has been sponsored by NSF, NASA, and the Smithsonian for nearly 40 years, returning thousands of meteorite samples. I was a member of the 1996 season. The six of us lived for six weeks in tents on the east Antarctic plateau, traversing regions of blue ice on snowmobiles hunting meteorites.

Antarctica is ideal for this search, for a number of reasons. Meteorites that fall into more temperate climates are hard to find among other terrestrial rocks; and they immediately start to rust in our atmosphere. But in Antarctica, they stand out on the white ice, and last, frozen, for thousands of years. Best of all, the motions of the ice tend to concentrate a continent's worth of falls into small regions of blue ice. It's just a matter of finding a region rich in meteorites and picking them up off the surface.

But by no means was it an easy experience. Living six weeks in a tent on an ice plain hundreds of kilometers from the next human settlement means that, ironically, it's dangerous to actually be alone. You depend on each other, because there's no one else there to do the physical work you need to do to survive. The six of us learned quickly how to drive each other nuts. And we became lifelong friends. For example I'm now the godfather to one of my campmate's children.

Q: *How did you get your interest in meteorites?*

A: I started college as a history major, but my best friend was studying at MIT. After spending a few weekends there, the atmosphere of the place (and the large science fiction library there!) so charmed me that I decided to transfer. I chose my major somewhat at random, thinking "Earth and Planetary Sciences" meant astronomy. It actually meant geology, as I discovered once I arrived. But I took a class on meteorites from Dr. John Lewis that was so much fun – he was a fantastic lecturer, full of stories and enthusiasm – that I couldn't wait to go to class. Eventually I stayed for a Master's thesis with him, before going on to Arizona to do my PhD.

Q: *What was the subject of your PhD?*

A: I began my PhD research with the late Mike Drake at Arizona, doing some really nice work on the chemical evolution of basaltic meteorites that turns out to be useful even today in understanding the results of the DAWN mission to Vesta, source of many of the basaltic meteorites. But I wanted to stretch myself more, so I chose to write my dissertation under Dr. Randy Jokipii on electromagnetism in the solar nebula. I learned a lot of physics, but not much about the solar nebula. Except for one small section on how electromagnetic forces and gravity forces interact to sculpt dust rings, a topic that others have carried far beyond what I started, that work has been pretty much ignored since I published it.

In fact, it was my master's thesis under John Lewis that has had the larger long-term effect. Lewis had the insight that the icy moons of the outer solar system contain a significant rocky component, and radioactive decay in these rocks could melt the ice and differentiate the moons. My project was to quantify this idea with a detailed computer model (written in the days of Fortran IV!) to trace how the heating, melting, decay, and differentiation would evolve with time. As a result we published the first quantitative model for an ocean under the crust of Jupiter's moon Europa, and we even were the first, as far as I know, to discuss the possibility of life in such an ocean. Shades of the science fiction that first attracted me to MIT!

This was all in 1975, long before the Voyager and Galileo spacecraft visited Jupiter. Years later, I was invited to co-author the first chapter of the Arizona Press Space Sciences volume on Europa. It was, alas the "history" chapter; all my work is now considered only of historical interest!

Q: *What is your current field of research?*

A: As I said, my own research interests started out in making models of asteroid and satellite thermal models. I soon discovered that there was a startling lack of data on the kinds of meteorite physical properties – density, porosity, thermal conductivity, heat capacity – that are necessary for such models. People like me simply assumed the rocky portions of these small bodies behaved like terrestrial basalts: a bad assumption, as it turns out.

So once I arrived at the Vatican Observatory, twenty years ago, with a large meteorite collection to work with, I started inventing some fast, cheap, and non-destructive ways of measuring these meteorite physical properties.

Recall, I was a theorist coming in, not a lab specialist. I knew the data I wanted, and I didn't know the traditional ways of taking those data. So I invented my own techniques, appropriate for meteorites. And I collaborated with a friend, Dan Britt, now at the University of Central Florida, who did have grant money for some of the larger bits of equipment. He also directed the PhD research of a younger Jesuit brother, Bob Macke, who first worked with me on this project in 2004 and is now a full time member of the Vatican Observatory staff himself.

For example, how do you measure a meteorite's density? Mass divided by volume! the mass is easy, but the traditional way of getting the volume by measuring a rock's displacement of water is terrible for meteorites. The water reacts with the sample (which is often rich in tiny flecks of metallic iron) and will partially enter into the meteorite's pore spaces. Instead, we put the sample in a beaker of known volume, fill the rest with small glass beads, and compare its weight with that of the beaker filled only with beads. From the difference you can calculate the meteorite's bulk density. The equipment needed is simple and portable, each measurement takes only a few minutes, and the beads can just be brushed off the sample.

Using measurements like these, combined with a commercial gas pycnometer for grain density measurements, we perfected the technique on our collection and then went and measured more than 1500 meteorite densities and porosities in collections all over the world. It's the data base everyone uses now to do things like compare meteorite densities with the densities of the asteroids they come from, and thus calculate the macro-porosity of different asteroid types. It turns out that, based on their densities, we find that most asteroids are not solid rocks, but rather loose piles of rubble.

At present, we're expanding our techniques to measure thermal properties. One promising technique is to drop a sample into liquid nitrogen, measure the mass of nitrogen boiled away as the meteorite cools down, and thus work out the meteorite's bulk heat capacity. I'll be busy over the next couple of years perfecting this system with our collection; and when we're ready, we can take that one on the road as well.

It turns out there's a big benefit to these sort of bulk physical measurements that we never even thought of when we started them. As I said, most meteorite chemical characterization is done with great precision on tiny bits of materials. But most meteorites are heterogeneous, in some cases on a scale of many tens of grams. How do you know that the bit you've measured is characteristic of the whole rock? By contrast, our measurement techniques non-destructively measure the whole rock. We've found that various meteorite types have distinctive densities, heat capacities, or magnetic properties. These bulk properties complement the chemical properties in allowing us to sort out the different meteorite types.

For example, enstatite-rich ordinary chondrites come in two chemically distinct groups, and the chemical analysis suggested one group was richer in metallic iron than the other; thus they have been called EL and EH types (for low- and high-metal). But our density and magnetic susceptibility measures show that while the EL and EH types are certainly different groups, they actually on average have similar metal contents. The metal content was not systematically measured by the chemists. You can imagine the consternation when we presented this result! But we convinced the referees, and it is part of the literature now.

Q: *Do you have a favorite meteorite in your collection?*

A: That's like asking if a parent has a favorite child. I love them all, each in their own way!

My Favorite Object

θ^1 Orionis C

Stefan Kraus

Discovered in February 1617 by Galileo Galilei during some of the first celestial telescopic observations ever conducted, the tight stellar group known as the Orion Trapezium has guided us towards understanding essential aspects of star formation. Nearly four centuries of research and technological progress later, the Trapezium still remains a unique laboratory to study the dynamics of open clusters and the early evolution of high-mass stars.

The most massive Trapezium star, θ^1C, is the primary source for the ultraviolet radiation that ionizes the Orion Nebula and photoevaporates the famous Orion proplyds. θ^1C was also the first O-star with a detected magnetic field (1.1 ± 0.1 kG, Donati et al. 2002) and is a well-studied binary (possibly triple) system that will undergo periastron passage later this year. Here, I briefly review the general properties of this intriguing O7V-type star (Simon-Diaz et al. 2006) and I encourage the community to conduct further observations on the system close to the upcoming periastron passage event.

A unique oblique magnetic rotator

Already in the 1970/80s, spectroscopic monitoring showed that the intensity and profile of various emission and absorption lines detected towards θ^1C vary in a strictly periodic manner (Conti 1972; Walborn 1981). A 15.422 day period was found in hydrogen recombination lines (Stahl et al. 1993, 1996, 2008; Walborn & Nichols 1994; Oudmaijer et al. 1997) and has been identified as the stellar rotation period. Stahl et al. (1996) pointed out that this periodicity can be explained by a large-scale dipolar magnetic field, whose axis is inclined with respect to the stellar rotation axis by $\sim 45°$. The rotation axis is inclined by $\sim 45°$ to the line of sight and maximum emission occurs when the magnetic pole crosses the sight line. ROSAT and later Chandra observations revealed hard, rotationally modulated X-ray emission towards θ^1C (Caillault et al. 1994; Gagné et al. 1997; Schulz et al. 2000), indicating the presence of a stable, compact shock region close to the stellar surface. Babel & Montmerle (1997) showed that these remarkable characteristics can be explained in the context of the magnetically confined wind shock (MCWS) model. This model, originally developed for magnetic Ap-Bp stars, describes how radiation-driven winds from both hemispheres are channeled along the magnetic field lines and collide at high velocities, forming a thin, nearly stationary shock region in the equatorial plane. Within this disk-like structure, the plasma co-rotates with the field lines, cools, and is then either transferred back onto the star or expelled an asymmetric wind. This scenario has been confirmed by the detection of the Zeeman signatures of a 1.15–1.80 kG magnetic field, whose strength modulates with the same period and phase as the diagnostic spectral lines (Donati et al. 2002; Wade et al. 2006). Some refinements to the wind geometry have been proposed (e.g. Smith & Fullerton 2005) and the geometry and physical conditions in the circumstellar magnetosphere have also been studied with detailed magnetohydrodynamic simulations in 2-D (Gagné et al. 2005) and 3-D (ud-Doula et al. 2013).

The multiple system

Besides its amazing properties as an oblique magnetic rotator, θ^1C was found to be a close multiple system (just as most other Trapezium stars; Preibisch et al. 1999). Speckle observations by Weigelt et al. (1999) discovered an early B-type companion (C2) at a separation of 33 mas from the primary (C1). We traced the orbital motion of this companion using visual-wavelength speckle interferometry as well as IOTA and VLTI infrared long-baseline interferometry, which resulted in the first dynamical orbit solution for the system, with a high-eccentricity, short-period orbit (Fig. 1; $e = 0.59 \pm 0.07$; $P = 11.26 \pm 0.05$ yr, Kraus et al. 2007, 2009) and semi-major axis $a = 44 \pm 3$ mas. Combining the constraints on the astrometric orbit with radial velocity measurements enables one to also determine the dynamical parallax of the system ($410 \pm 20 M_\odot$) as well as the system mass ($M_{C1} + M_{C2} = 44 \pm 7 M_\odot$) and the mass ratio of the two components ($M_{C2}/M_{C1} = 0.23 \pm 0.05$, Kraus et al. 2009).

Vitrichenko (2002) and Lehmann et al. (2010) performed a multi-frequency analysis on an extensive data set of radial velocity measurements on θ^1C and identified a period of 61.49 days, which they assign to a potential third stellar component (C3). The orbit of C3 would be in a 1:4

resonance with the stellar rotation and have a high eccentricity ($e = 0.49$), contrary to the expectation that the orbit should have been circularized by tidal interaction with the massive primary. Assuming that the orbit of this inner companion is coplanar with the orbit of the long-period companion (C2), Lehmann et al. estimate the mass of C3 to $\sim 1\,\mathrm{M}_{\odot}$ and the semi-major axis to 0.82 ± 0.26 AU. Clearly, follow-up observations are needed in order to confirm the detection of this third component, to measure its astrometric orbit, and to estimate whether the companion might cause other observable effects, for instance through interaction with the magnetosphere of the primary star.

Dynamical history of the θ^1C system

The dynamical history of the Trapezium and the Orion Nebula Cluster has been the subject of a plethora of studies. Early radial velocity studies suggested that θ^1C might have an anomalous high radial velocity and might be moving at a relative velocity of $13\,\mathrm{km\,s^{-1}}$ with respect to the ONC rest frame (O'Dell et al. 2009). However, more recent orbit solutions determine the heliocentric systemic radial velocity of the θ^1C system to $\gamma \approx 23\,\mathrm{km\,s^{-1}}$ (Kraus et al. 2009; Lehmann et al. 2010), which is within the observed velocity dispersion of the other Trapezium stars ($24 \pm 3\,\mathrm{km\,s^{-1}}$, Abt et al. 1991) and the Orion Molecular Cluster ($25.8 \pm 1.7\,\mathrm{km\,s^{-1}}$, O'Dell et al. 2008).

An interesting scenario on the dynamical history of the θ^1C system was presented by Tan (2004). Based on proper motion measurements, he proposed that the Becklin-Neugebauer (BN) object that is located 45" to the northwest of the Trapezium stars might be a runaway B star ejected from the θ^1C system about 4500 years ago. In this case, one would expect that the parent system should recoil in the opposite direction. In fact, θ^1C shows a proper motion to the south-east, aligned just in the opposite direction than the proper motion of BN. In this scenario, BN encountered the Kleinmann-Low (KL) star-forming core by chance, where it triggered tidally enhanced accretion and outflow activity. The low likelihood for such a chance encounter is one of the major challenges for this scenario and alternative BN ejection scenarios that do not involve θ^1C have been proposed (e.g. Bally & Zinnecker 2005; Gómez et al. 2005, 2008; Zapata et al. 2009; Bally et al. 2011). Nevertheless, the θ^1C-BN ejection scenario provides a good explanation for the 3-D velocity, orbit orientation, mass ratio, and eccentricity of the θ^1C binary system. Chatterjee & Tan (2012) estimated the probability that θ^1C has these characteristics by chance to less than 10^{-5}. These simulations did not yet include the putative low-mass ($\sim 1\,\mathrm{M}_{\odot}$) component C3 that has been proposed by Lehmann et al. (2010) and it seems unlikely that this low-mass component could have survived the dynamical interaction that lead to the ejection of BN. Therefore, it will be important to confirm the existence of the putative C3 low-mass component, to establish its orbital characteristics, and then to re-evaluate the probability that this system could have been involved in the BN ejection event.

The upcoming periastron passage event

We predict the next periastron passage of C1-C2 to take place between September and November this year (2013.83 ± 0.1). The decreased angular separation (~ 2.8 mas) will provide an opportunity for employing the latest optical interferometric observing techniques, such as the high spectral dispersion modes that are available at the VLTI and CHARA array. These observations are difficult to perform when the separation of the system is of the order of tens of milliarcseconds, as the distant companion then causes rapid fringe contrast modulations and bandwidth-smearing effects that limit the achievable signal-to-noise ratio. These limitations are relaxed close to periastron passage, which should enable interferometric studies with high spectral dispersion in emission lines like Hα or Brγ. Such observations could reveal the distribution and kinematics of hot shocked gas on scales of (sub-)stellar radii, providing the first spatially resolved constraints on the magnetically confined wind-shock region around θ^1C and a direct measurement of the rotation-modulated changes that are responsible for the spectroscopic variability.

New spectroscopic observations close to the periastron passage event will be essential to improve the dynamical orbit of the long-period companion and possibly to confirm the putative third component and to detect the photospheric lines of the companion C2. At their closest approach, the physical separation between C1 and C2 will still be ~ 7 AU, which makes it unlikely that any wind-wind interaction events between these components can be detected.

I would like to acknowledge my collaborators on our past and ongoing interferometry projects on θ^1C, including Fabien Baron, Xiao Che, Rebekka Grellmann, Florentin Millour, John Monnier, Denis Mourard, Thomas Preibisch, Gerd Weigelt, and the members of the CHARA, MIRC, and VEGA groups.

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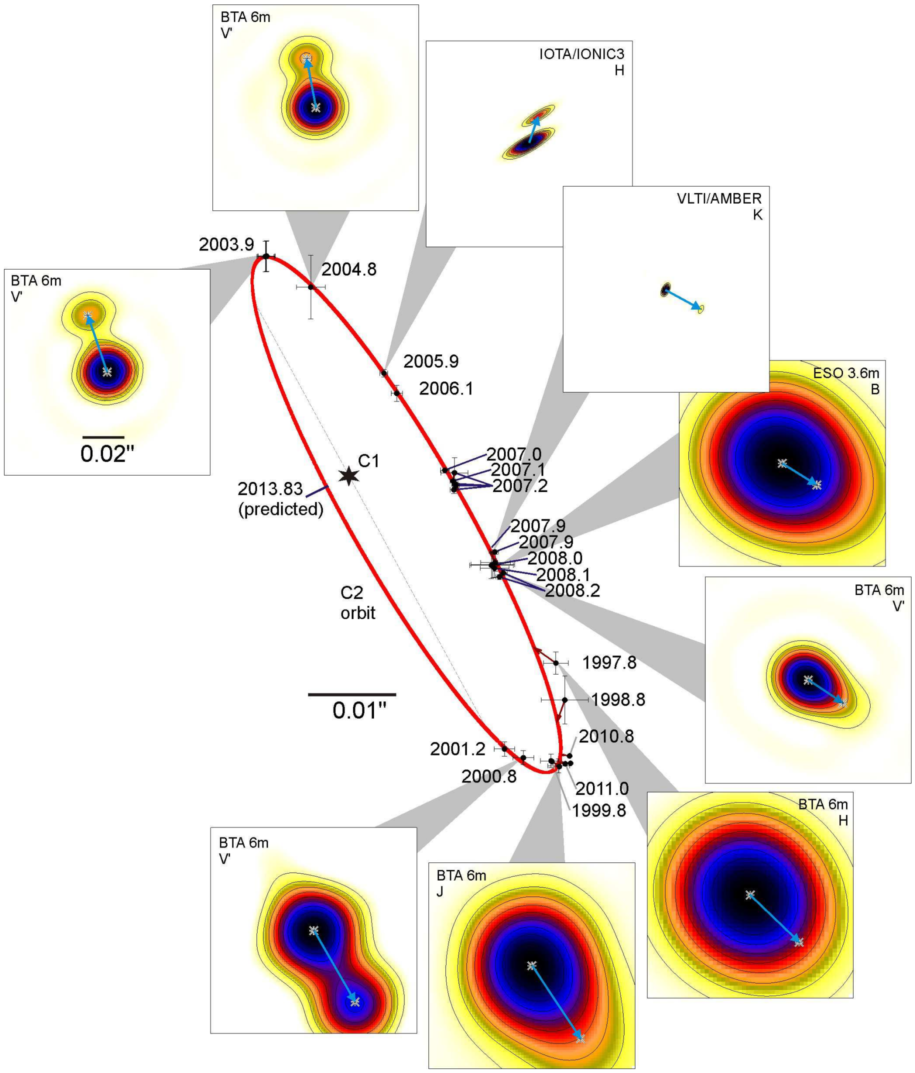

Figure 1: Astrometric measurements of the θ^1 Ori C1-C2 binary system (Weigelt et al. 1999; Schertl et al. 2003; Kraus et al. 2007; Patience et al. 2008; Kraus et al. 2009; Grellmann et al. 2013), overplotted with the best-fit orbit solution from Kraus et al. (2009). The insets show interferometric images that have been reconstructed from speckle (Weigelt et al. 1999; Schertl et al. 2003; Kraus et al. 2007) as well as IOTA (Kraus et al. 2007) and VLTI (Kraus et al. 2009) long-baseline interferometric observations at various epochs.

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Perspective

Resolved Star Formation in the Magellanic Clouds

by Joana M. Oliveira

1 Context

As the nearest gas-rich galaxies in the Local Group, the Large and Small Magellanic Clouds (LMC and SMC, respectively at 50 and 60 kpc, Ngeow & Kanbur 2008, Szewczyk et al. 2009) represent a superb hunting ground for any resolved stellar studies. These metal-deficient galaxies ($Z_{\rm SMC} \sim 0.2 Z_\odot$ and $Z_{\rm LMC} \sim 0.4 Z_\odot$, e.g. Russell & Dopita 1992) are often touted as templates for star formation conditions in the metal-poor early Universe. Obviously the ISM metallicity in the Clouds is not extremely low in absolute terms, however these environments do provide an invaluable and relevant window into a region of parameter space that has so far been observationally unexplored. Metallicity reveals itself in at least two ways: abundances of gas-phase carbon and oxygen (and their molecular products), and abundance and properties of dust grains. The most efficient cooling mechanisms during the early collapse stages are via radiation through fine structure lines of C and O, as well as rotational transitions in abundant molecules such as water (e.g., van Dishoeck 2004). Furthermore, dust grains are crucial in driving molecular cloud chemistry, as dust opacity shields cores from radiation, and grain surfaces enable chemical reactions to occur that would not happen in the gas phase. Even over the metallicity range covered by the Galaxy and the Magellanic Clouds (MCs), cooling, chemistry rates and star formation timescales could be affected (Banerji et al. 2009).

The MCs also offer the exciting new opportunity of bridging the gap between star formation processes on large galactic-wide scales and on the small scales of individual Young Stellar Objects (YSOs). The Spitzer Space Telescope and more recently the Herschel Space Observatory allowed us to survey most of the Magellanic System in a relatively unbiased way. For the first time, it is possible to perform a complete census of star formation across the whole galaxies, relating the young stellar population with the extensively studied galactic structure, and gas and dust distributions. The MCs are however still near enough to resolve individual YSOs, so that the detail of the star formation process can also be investigated. It is important to recognise the spatial-scale limitations of such surveys. If we consider that the Trapezium OB stars occupy a region of $\sim 21''$ at a distance of 450 pc (Hillenbrand 1997), this corresponds to $\sim 0.16''$ and $\sim 0.19''$ respectively at the distances of the SMC and the LMC. This implies that in general objects described as massive YSOs in the MCs are more likely to be small protoclusters, even if their IR signature is dominated by a single or a few massive objects.

2 Pre-Spitzer era

Prior to galaxy-wide IR surveys (see below) star formation studies in the MCs focused on selected star-forming regions. By far the best studied region in the LMC is 30 Doradus or the Tarantula nebula, the only (mini-)starburst in the Local Group. At the core of the 30 Dor complex is R 136, suggested to be an interacting double cluster with an age < 5 Myr (Sabbi et al. 2012). In the extended multi-stage star forming region (Sabbi et al. 2013 and references therein), several generations of stars coexist, from an older population (< 25 Myr) to the northwest of the central cluster to an emerging population of embedded YSOs (< 0.5 Myr) lodged in the interface between the expanding cavity centered on R 136 and the remnant giant molecular cloud to the west and northeast (Walborn et al. 2013). Very recently, Sabbi et al. (2013) reported on an ongoing HST treasury project for the whole star forming complex. A number of smaller star forming regions in the LMC have also been studied, either in terms of their pre-main-sequence (PMS) content (e.g. da Rio et al. 2009) or ongoing star formation (e.g. Carlson et al. 2012).

Most earlier studies of MC star forming regions made use of the Hubble Space Telescope and its ACS instrument, and were therefore aimed at analysing the less reddened/embedded, lower-mass PMS population. Two regions in the SMC are particularly interesting since they provide insight into potentially distinct star formation conditions. NGC 346 is a young and active cluster that excites N 66, the largest and brightest H II region in the

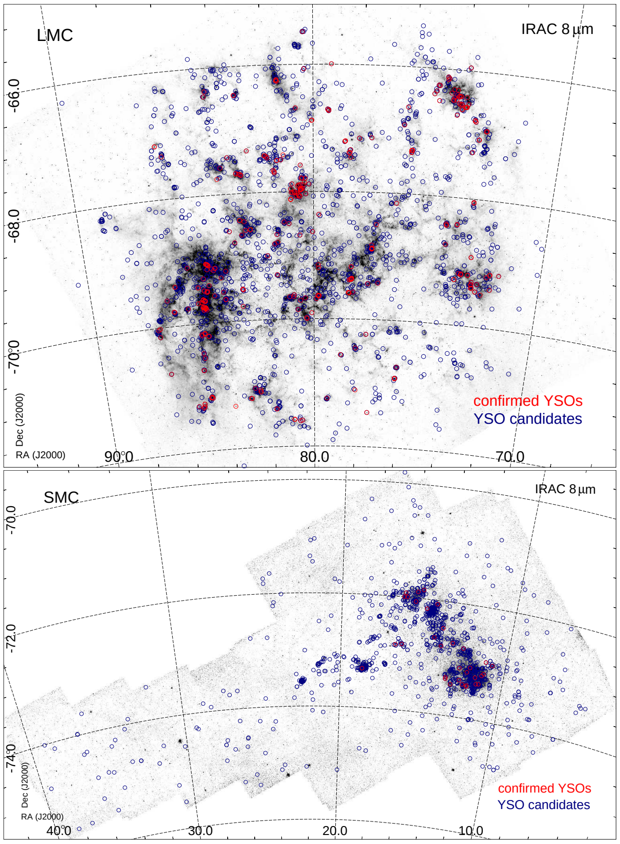

Figure 1: YSOs identified in the MCs (Sewiło et al. 2013); photometric candidates and spectroscopically confirmed sources appear respectively in blue and red.

SMC. This cluster contains a major fraction of the O stars (> 30) known in the entire SMC. HST studies describe the complex sub-structured PMS content of NGC 346; a recent burst of star formation occurred around 3−5 Myr ago but there is also an older population (> 10 Myr), and star formation is still ongoing in denser regions. The star formation rate (SFR) peaked at $20\,M_\odot\,yr^{-1}\,kpc^{-2}$ about $4-5$ Myr ago (Cignoni et al. 2011), with a lower present day rate ($\sim 0.07\,M_\odot\,yr^{-1}\,kpc^{-2}$, Simon et al. 2007).

NGC 602 and the H II region N90 it excites are located at the boundary between the SMC Wing and the Magellanic Bridge; the complex is probably the result of the interaction of two expanding H I shells. The central cluster is younger than 5 Myr, and star formation is ongoing in the outskirts of the excited gas bubble; propagation of star formation is most likely driven by radiation with stars forming along the edges of the photodissociation region, since the shell expansion velocities are negligible (Carlson et al. 2011 and references therein). The SFR peaked at $\sim 0.09-0.2\,M_\odot\,yr^{-1}\,kpc^{-2}$ about 2.5 Myr ago (Cignoni et al. 2009); the present day rate is $0.14-0.71\,M_\odot\,yr^{-1}\,kpc^{-2}$ (Carlson et al. 2011). This is comparable to small-scale Galactic star-forming regions, despite the fact that the low gas and dust densities in the region are not in principle favourable to star formation.

It is important to point out that in these examples SFRs are computed either using population synthesis or YSO counts. Different methods use different theoretical assumption, the mass ranges considered and characteristic timescales are different, and distinct star formation episodes occur over different spatial scales. Therefore, comparing SFRs over relatively small areas can be tricky.

The Initial Mass function (IMF) is another important tool to indirectly infer how the star formation process may be affected by the environment. A number of authors have studied the IMF of young populations in both MCs (e.g. Sabbi et al. 2008; da Rio et al. 2009): when compared to typical Galactic PMS populations, no conclusive indication of an environmental signature has been found so far, i.e. the IMF is well described by a Salpeter slope at higher masses, with a turnover at subsolar masses.

3 Spitzer and Herschel eras

The Spitzer Space Telescope allowed the most complete IR census of the stellar content of both MCs. As a result the Legacy surveys SAGE (Meixner et al. 2006) and SAGE-SMC (Gordon et al. 2011) revolutionised star formation studies outside the Galaxy. Since YSOs become less red as they evolve, these surveys identify mostly massive Class/Stage I sources, i.e. embedded YSOs with spectral energy distributions (SEDs) peaking around $100\,\mu$m (see discussion below). Figure 1 shows the location of YSOs identified in the MCs, superposed on $8\,\mu$m maps; prior to the launch of Spitzer about 20 YSOs were known across the two galaxies. The Herschel Legacy program (HERITAGE, Meixner et al. 2010) is revealing the youngest, most embedded Class/Stage 0 YSOs, that are only accessible at far-IR wavelengths (Sewiło et al. 2010).

The first challenge introduced by these galaxy-wide surveys is how to identify YSOs. Most of the studies mentioned above rely on using massive OB stars and the associated H II regions as signposts of recent and current star formation. In order to perform an unbiased inventory of star formation across the galaxies an IR-based photometric method is required. The identification relies on the fact that YSOs are redder than many other populations. Two other classes of astronomical objects can contaminate YSO samples over large areas: dusty evolved stars (at the brighter end) and unresolved background galaxies (at the fainter end). This is nicely demonstrated in Fig. 2, that shows in a color-magnitude diagram (CMD) constructed using SAGE-SMC photometry, the location of different classes of evolved stars, YSOs and galaxies, as well as the

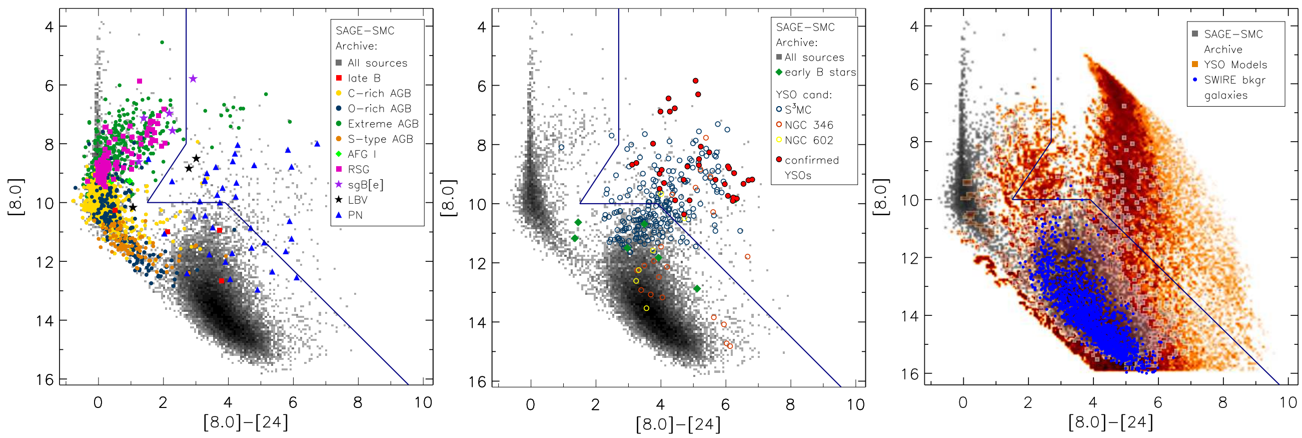

Figure 2: SAGE-SMC CMD showing location of contaminants, YSOs and predictions from SED YSO models (Sewiło et al. 2013).

predictions of YSO models.

In the LMC, Whitney et al. (2008, W08) and Gruendl & Chu (2009, GC09) used SAGE data to identify YSO candidates. These two works are complementary: W08 used fairly stringent point-source criteria (excluding marginally extended YSOs) but including fainter sources; GC09 have a shallower flux cut but use a combination of aperture photometry and visual inspection of SEDs and images, therefore including marginally extended YSOs as well as objects that sit in regions with complex background. In total $\sim$ 1800 YSOs have been identified in the LMC. Crucially these surveys are incomplete in the sense that they miss the earliest Class/Stage 0 sources, less embedded objects (Classes/Stages II and III) and less luminous (lower mass) sources in general. This is probably the best that can be achieved in terms of identifying YSOs over a whole galaxy, given the large numbers of possible contaminants. Carlson et al. (2012) have shown that if known/suspected star forming regions are targeted, the color cuts can be relaxed and a more complete census of lower luminosity sources can be performed.

The S^{3}MC survey (Bolatto et al. 2007) identified $\sim$ 300 YSO candidates; using data from the SAGE-SMC survey (that extends the S^{3}MC survey both in area covered and sensitivity), Sewiło et al. (2013) identified $\sim$ 1200 YSOs in the SMC. Their method is an hybrid of the W08 and GC09 approaches, using optical to mid-IR PSF and aperture photometry, as well as multi-wavelength images. Using YSO counts, Sewiło et al. (2013) estimate a global galaxy-wide SFR in the SMC of $\sim 0.02\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$; W08 use a similar method to compute a SFR of $\sim 0.06\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ for the LMC. For comparison, recent calculations estimate SFR$\sim 1.9\,\mathrm{M}_\odot\,\mathrm{yr}^{-1}$ for the Galaxy (see Kennicutt & Evans 2012 for a review).

4 Spectroscopic YSO surveys

The existence of such sizeable samples naturally led to several spectroscopic follow-up surveys of massive YSOs in the MCs. Using Spitzer-IRS, Oliveira et al. (2009), Seale et al. (2009) and Woods et al. (2011) confirmed the YSO nature of about $\sim$ 300 sources in the LMC (see also Shimonishi et al. 2010), while Oliveira et al. (2011, 2013) analysed the spectra of 33 sources in the SMC.

Mid-IR spectra are used to investigate the nature of the YSO candidates; the following spectral features, superposed on a very red continuum are considered: absorption features attributed to silicate dust and ice species in the cold dense YSO environments, and emission features attributed to polycyclic aromatic hydrocarbons (PAHs) and fine structure emission of ionised gas. These two types of spectral features represent a rough sequence of massive YSO evolution, from deeply embedded sources with a rich chemistry to compact H II regions as the emerging massive star acts on its near-environs. Such classifications do not make a statement about the spatial scale of the objects ($1''$ corresponds to 0.25-0.3 pc in the MCs). Furthermore given the spatial resolution of Spitzer, it is very likely that different regions of the YSO environment (with distinct temperature and density structures, and chemistry) are sampled by the observing beam.

A smaller number of objects exhibit emission features attributed to silicate dust; such objects are likely intermediate-mass YSOs, MC analogs of Galactic HAeBe objects with circumstellar disks and/or tenuous envelopes where the silicate dust is further processed.

In cold molecular clouds, layers of ice form on the surface of dust grains. H_2O is by far the most abundant ice species, followed by CO_2 and CO. Understanding ice chemistry is crucial to understanding the gas-phase chemistry and to probing the physical conditions within molecular clouds. Since ice chemistry offers a window into the star formation process, particular attention was dedicated to a subsample of LMC and SMC sources that exhibit absorption features attributed to circumstellar ices. The IRS spectral range includes features from two of the major species mentioned above. The CO_2 ice feature at $15.2\,\mu$m sits in a relatively uncomplicated spectral region. The $5-7\,\mu$m ice complex is due to a mixture of many species: H_2O, NH_3, CH_3OH, HCOOH and H_2CO ices; specially for sources with a rich PAH emission spectrum (see above), the contribution of H_2O ice at $\sim 6\,\mu$m is very difficult to isolate. Features due to H_2O ice (at $3.1\,\mu$m) and CO ice (at $4.67\,\mu$m) have been observed with groundbased instrumentation or the AKARI satellite. In the LMC and by comparison to Galactic samples, CO_2 ice column densities are enhanced with respect to H_2O ice (Oliveira et al. 2009; Shimonishi et al. 2010; Seale et al. 2011), while relative CO-to-CO_2 abundances are unchanged (Oliveira et al. 2011). CO_2 production (CO_2 forms exclusively on grain mantles) could be enhanced due to the stronger UV field and/or higher dust temperatures in the LMC (an indirect effect of the lower LMC metallicity). However harsher conditions would destroy CO ice (the most volatile of these three ice species), something that is not observed in the LMC. Instead Oliveira et al. (2011) suggest that H_2O ice could be depleted due to the combined effects of a lower gas-to-dust ratio and stronger UV radiation field.

In a small sample of SMC YSOs, Oliveira et al. (2011) do not detect any CO ice signatures. This could be an indication that the even harsher conditions in SMC environments prevent the survival of volatile ice species. However, H_2O and CO_2 ices are detected. In the SMC CO_2 column densities do not seem generally enhanced when compared to LMC and Galactic samples (Fig. 3, Oliveira et al. 2013). This argues against an enhanced level of processing resulting from a harsher environment in a metal-poor environment. In Galactic sources the two ice species generally coexist, suggesting that CO_2 ice forms just as easily and as widely as H_2O ice (chemical pathways exist for H_2O formation both in the gas-phase and on grain surfaces). Figure 3 suggests this is not the case in all conditions, since for the SMC sample there is a very strong suggestion of a H_2O threshold for the detection of CO_2 ice. The SMC analysis however does not help clarify whether H_2O ice is depleted in low metallicity environments.

Star formation research in the MCs is full of exciting challenges. Herschel surveys will census earlier stage YSOs, and will provide the first study of gas chemistry and the YSO cooling process. ALMA is starting to dissect MC star forming regions and gas structure at unprecedented spatial scales (Indebetouw et al. 2013). And the James Webb Telescope will allow us not only to resolve smaller spatial

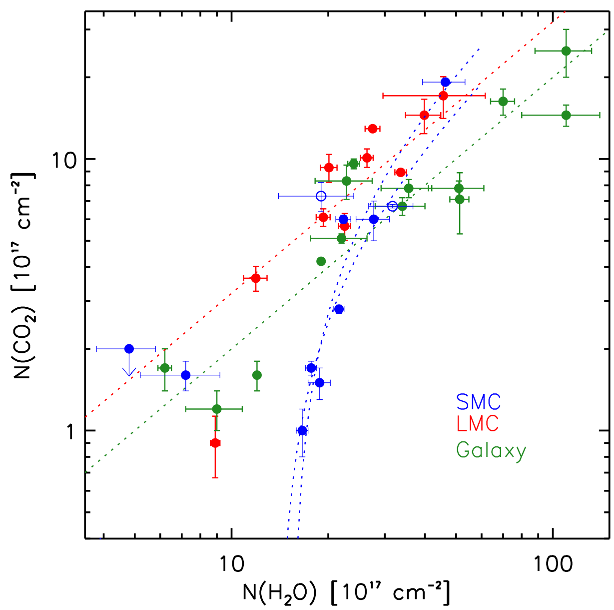

Figure 3: Observed H_2O and CO_2 ice column densities (Oliveira et al. 2013).

scales at IR wavelengths and less massive YSOs, but also to perform MC-like studies in more distant galaxies.

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Abstracts of recently accepted papers

A Pan-STARRS + UKIDSS Search for Young, Wide Planetary-Mass Companions in Upper Scorpius

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We have combined optical and NIR photometry from Pan-STARRS 1 and UKIDSS to search the young (5–10 Myr) star-forming region of Upper Scorpius for wide ($\approx$400–4000 AU) substellar companions down to $\sim 5\,M_{Jup}$. Our search is $\approx$4 mag deeper than previous work based on 2MASS. We identified several candidates around known stellar members using a combination of color selection and spectral energy distribution fitting. Our followup spectroscopy has identified two new companions as well as confirmed two companions previously identified from photometry, with spectral types of M7.5-M9 and masses of $\sim$15–60 M_{Jup}, indicating a frequency for such wide substellar companions of $\sim 0.6 \pm 0.3\%$. Both USco 1610−1913B and USco 1612−1800B are more luminous than expected for their spectral type compared with known members of Upper Sco. HIP 77900B has an extreme mass ratio ($M_2/M_1 \approx 0.005$) and an extreme separation of 3200 AU. USco 1602−2401B also has a very large separation of 1000 AU. We have also confirmed a low-mass stellar companion, USco 1610−2502B (730 AU, M5.5). Our substellar companions appear both non-coeval with their primary stars according to evolutionary models and, as a group, are systematically more luminous than the Upper Sco cluster sequence. One possible reason for these luminosity discrepancies could be different formation processes or accretion histories for these objects.

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Pre-main-sequence isochrones - II. Revising star and planet formation time-scales

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We have derived ages for 13 young (< 30 Myr) star-forming regions and find they are up to a factor of 2 older than the ages typically adopted in the literature. This result has wide-ranging implications, including that circumstellar discs survive longer ($\simeq 10-12$ Myr) and that the average Class I lifetime is greater ($\simeq 1$ Myr) than currently believed. For each star-forming region we derived two ages from colour-magnitude diagrams. First we fitted models of the evolution between the zero-age main-sequence and terminal-age main-sequence to derive a homogeneous set of main-sequence ages, distances and reddenings with statistically meaningful uncertainties. Our second age for each star-forming region was derived by fitting pre-main-sequence stars to new semi-empirical model isochrones. For the first time (for a set of clusters younger than 50 Myr) we find broad agreement between these two ages, and since these are derived from two distinct mass regimes that rely on different aspects of stellar physics, it gives us confidence in the new age scale. This agreement is largely due to our adoption of empirical colour-$T_{\rm eff}$ relations and bolometric corrections for pre-main-sequence stars cooler than 4000 K.
The revised ages for the star-forming regions in our sample are: ~ 2 Myr for NGC 6611 (Eagle Nebula; M 16), IC 5146

(Cocoon Nebula), NGC 6530 (Lagoon Nebula; M 8), and NGC 2244 (Rosette Nebula); ~ 6 Myr for σ Ori, Cep OB3b, and IC 348; $\simeq 10$ Myr for λ Ori (Collinder 69); $\simeq 11$ Myr for NGC 2169; $\simeq 12$ Myr for NGC 2362; $\simeq 13$ Myr for NGC 7160; $\simeq 14$ Myr for χ Per (NGC 884); and $\simeq 20$ Myr for NGC 1960 (M 36).

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The short-lived production of exozodiacal dust in the aftermath of a dynamical instability in planetary systems.

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Excess emission, associated with warm, dust belts, commonly known as exozodis, has been observed around a third of nearby stars. The high levels of dust required to explain the observations are not generally consistent with steady-state evolution. A common suggestion is that the dust results from the aftermath of a dynamical instability, an event akin to the Solar System's Late Heavy Bombardment. In this work, we use a database of N-body simulations to investigate the aftermath of dynamical instabilities between giant planets in systems with outer planetesimal belts. We find that, whilst there is a significant increase in the mass of material scattered into the inner regions of the planetary system following an instability, this is a short-lived effect. Using the maximum lifetime of this material, we determine that even if every star has a planetary system that goes unstable, there is a very low probability that we observe more than a maximum of 1% of sun-like stars in the aftermath of an instability, and that the fraction of planetary systems currently in the aftermath of an instability is more likely to be limited to ¡0.06%. This probability increases marginally for younger or higher mass stars. We conclude that the production of warm dust in the aftermath of dynamical instabilities is too short-lived to be the dominant source of the abundantly observed exozodiacal dust.

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Mixing and Transport of Short-Lived and Stable Isotopes and Refractory Grains in Protoplanetary Disks

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Analyses of primitive meteorites and cometary samples have shown that the solar nebula must have experienced a phase of large-scale outward transport of small refractory grains as well as homogenization of initially spatially heterogeneous short-lived isotopes. The stable oxygen isotopes, however, were able to remain spatially heterogenous at the $\sim 6\%$ level. One promising mechanism for achieving these disparate goals is the mixing and transport associated with a marginally gravitationally unstable (MGU) disk, a likely cause of FU Orionis events in young low-mass stars. Several new sets of MGU models are presented that explore mixing and transport in disks with varied masses (0.016 to 0.13 $M_\odot$) around stars with varied masses (0.1 to 1 $M_\odot$) and varied initial Q stability minima (1.8 to 3.1). The results show that MGU disks are able to rapidly (within $\sim 10^4$ yr) achieve large-scale transport and homogenization of initially spatially heterogeneous distributions of disk grains or gas. In addition, the models show that while single-shot injection heterogeneity is reduced to a relatively low level ($\sim 1\%$), as required for early solar system chronometry, continuous injection of the sort associated with the generation of stable oxygen isotope fractionations by UV photolysis leads to a sustained, relatively high level ($\sim 10\%$) of heterogeneity, in agreement with the oxygen isotope data. These models support the suggestion that the protosun may have experienced at least one FU Orionis-like outburst, which

produced several of the signatures left behind in primitive chondrites and comets.

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http://www.dtm.ciw/users/boss/ftp/mixtrans.pdf

The Dependence of Star Formation Efficiency on Gas Surface Density

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Studies by Lada et al. (2010) and Heiderman et al. 2010 have suggested that star formation mostly occurs above a threshold in gas surface density Σ of $\Sigma_c \sim 120\, M_\odot\, \mathrm{pc}^{-2}$ ($A_K \sim 0.8$). Heiderman et al. infer a threshold by combining low-mass star-forming regions, which show a steep increase in the star formation rate per unit area Σ_{SFR} with increasing Σ, and massive cores forming luminous stars which show a linear relation. We argue that these observations do not require a particular density threshold. The steep dependence of Σ_{SFR}, approaching unity at protostellar core densities, is a natural result of the increasing importance of self-gravity at high densities along with the corresponding decrease in evolutionary timescales. The linear behavior of Σ_{SFR} vs. Σ in massive cores is consistent with probing dense gas in gravitational collapse, forming stars at a characteristic free-fall timescale given by the use of a particular molecular tracer. The low-mass and high-mass regions show different correlations between gas surface density and the area A spanned at that density, with $A \sim \Sigma^{-3}$ for low-mass regions and $A \sim \Sigma^{-1}$ for the massive cores; this difference, along with the use of differing techniques to measure gas surface density and star formation, suggests that connecting the low-mass regions with massive cores is problematic. We show that the approximately linear relationship between dense gas mass and stellar mass used by Lada et al. similarly does not demand a particular threshold for star formation, and requires *continuing* formation of dense gas. Our results are consistent with molecular clouds forming by galactic hydrodynamic flows with subsequent gravitational collapse.

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Near-infrared imaging polarimetry of HD142527

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HD 142527 is a pre-transition disk with strong evidence for ongoing planet formation. Recent observations show a disrupted disk with spiral arms, a dust-depleted inner cavity and the possible presence of gas streams driving gas from the outer disk toward the central star. We aim to derive the morphology of the disk and the distribution and properties of the dust at its surface. We have obtained polarized differential images of HD 142527 at H and Ks bands with NaCo at the VLT. Combining these images with classical PSF-subtraction, we are able to derive the polarization degree of this disk. At H band the polarization degree of the disk varies between 10% and 25%. This result cannot be reproduced by dust distributions containing highly porous material. The polarization is better matched by distributions of compact particles, with maximum sizes at least up to a few microns, in agreement with previous observations. We also observe two regions of low emission (nulls) in total and in polarized intensity. In particular, one of these nulls is at roughly the same position as the maximum of the horse-shoe shape observed in submillimeter continuum emission ALMA band-7 (345 GHz) observations. We discuss the possible link between these two features.

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Exclusion of Cosmic Rays in Protoplanetary Disks: Stellar and Magnetic Effects

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Cosmic rays (CRs) are thought to provide an important source of ionization in the outermost and densest regions of protoplanetary disks; however, it is unknown to what degree they are physically present. As is observed in the Solar System, stellar winds can inhibit the propagation of cosmic rays within the circumstellar environment and subsequently into the disk. In this work, we explore the hitherto neglected effects of cosmic ray modulation by both stellar winds and magnetic field structures and study how these processes act to reduce disk ionization rates. We construct a two-dimensional protoplanetary disk model of a T-Tauri star system, focusing on ionization from stellar and interstellar FUV, stellar X-ray photons, and cosmic rays. We show that stellar winds can power a Heliosphere-like analogue, i.e., a "T-Tauriosphere," diminishing cosmic ray ionization rates by several orders of magnitude at low to moderate CR energies ($E_{\rm CR} \leq 1$ GeV). We explore models of both the observed solar wind cosmic ray modulation and a highly simplified estimate for "elevated" cosmic ray modulation as would be expected from a young T-Tauri star. In the former (solar analogue) case, we estimate the ionization rate from galactic cosmic rays to be $\zeta_{\rm CR} \sim (0.23-1.4)\times10^{-18}$ s^{-1}. This range of values, which we consider to be the maximum CR ionization rate for the disk, is more than an order of magnitude lower than what is generally assumed in current models for disk chemistry and physics. In the latter elevated case, i.e., for a "T-Tauriosphere," the ionization rate by cosmic rays is $\zeta_{\rm CR} \lesssim 10^{-20}$ s^{-1}, which is 1000 times smaller than the interstellar value. We discuss the implications of a diminished cosmic ray ionization rate on the gas physics by estimating the size of the resulting MRI dead zones. Indeed, if winds are as efficient at cosmic ray modulation as predicted here, short-lived radionuclides (now extinct) would have provided the major source of ionization ($\zeta_{\rm RN} \sim 7.3 \times 10^{-19}$ s^{-1}) in the planet-forming zone of the young Solar Nebula.

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A young hierarchical triple system harbouring a candidate debris disc

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We report the detection of a wide young hierarchical triple system where the primary has a candidate debris disc. The primary, TYC 5241-986-1 A, is a known Tycho star which we classify as a late-K star with emission in the X-ray, near and far-UV and Hα suggestive of youth. Its proper motion, photometric distance (65–105 pc) and radial velocity lead us to associate the system with the broadly defined Local Association of young stars but not specifically with any young moving group. The presence of weak lithium absorption and X-ray and calcium H and K emission support an age in the 20 to ~125 Myr range. The secondary is a pair of M4.5±0.5 dwarfs with near and far UV and Hα emission separated by approximately 1″ (~650-105 AU projected separation) which lie 145″ (9200–15200 AU) from the primary. The primary has a WISE 22 micron excess and follow-up Herschel observations also detect an excess at 70 μm. The excess emissions are indicative of a 100–175 K debris disc. We also explore the possibility that this excess could be due to a coincident background galaxy and conclude that this is unlikely. Debris discs are extremely rare

around stars older than 15 Myr, hence if the excess is caused by a disc this is an extremely novel system.

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The 0.5-2.22 μm Scattered Light Spectrum of the Disk Around TW Hya: Detection of a Partially Filled Disk Gap at 80 AU

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We present a 0.5-2.2 μm scattered light spectrum of the circumstellar disk around TW Hya from a combination of spatially resolved HST STIS spectroscopy and NICMOS coronagraphic images of the disk. We investigate the morphology of the disk at distances >40 AU over this wide range of wavelengths, and identify the presence of a depression in surface brightness at ∼80 AU that could be caused by a gap in the disk. Additionally, we quantify the surface brightness, azimuthal symmetry, and spectral character of the disk as a function of radius. Our analysis shows that the scattering efficiency of the dust is largely neutral to blue over the observed wavelengths. We model the disk as a steady alpha-disk with an ad hoc gap structure. The thermal properties of the disk are self-consistently calculated using a three-dimensional radiative transfer code that uses ray-tracing to model the heating of the disk interior and scattered light images. We find a good fit to the data over a wide range of distances from the star if we use a model disk with a partially filled gap of 30% depth at 80 AU and with a self-similar truncation knee at 100 AU. The origin of the gap is unclear, but it could arise from a transition in the nature of the disk's dust composition or the presence of a planetary companion. Based on scalings to previous hydrodynamic simulations of gap opening criteria for embedded proto-planets, we estimate that a planetary companion forming the gap could have a mass between 6–28 $M_\oplus$.

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Modification of the MOOG spectral synthesis codes to account for Zeeman broadening of spectral lines

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In an attempt to widen access to the study of magnetic fields in stellar astronomy, I present MOOGStokes, a version of the MOOG one-dimensional LTE radiative transfer code, overhauled to incorporate a Stokes vector treatment of polarized radiation through a magnetic medium. MOOGStokes is a suite of three complementary programs, which together can synthesize the disk-averaged emergent spectrum of a star with a magnetic field. The first element (a pre-processing script called CounterPoint) calculates for a given magnetic field strength, wavelength shifts and polarizations for the components of Zeeman sensitive lines. The second element (a MOOG driver called SynStokes derived from the existing MOOG driver Synth) uses the list of Zeeman shifted absorption lines together with the existing machinery of MOOG to synthesize the emergent spectrum at numerous locations across the stellar disk, accounting for stellar and magnetic field geometry. The third and final element (a post-processing script called DiskoBall) calculates the disk-averaged spectrum by weighting the individual emergent spectra by limb darkening and projected area, and applying the effects of Doppler broadening. All together, the MOOGStokes package allows users to synthesize emergent spectra of stars with magnetic fields in a familiar computational framework. MOOGStokes produces disk-averaged spectra for all Stokes vectors $(\mathbf{I}, \mathbf{Q}, \mathbf{U}, \mathbf{V})$, normalized by the continuum. MOOGStokes agrees well with the predictions of INVERS10 a polarized radiative transfer code with a long history of use in the study of stellar magnetic fields. In the non-magnetic limit, MOOGStokes also agrees with the predictions of the scalar version of MOOG.

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GASPS - a Herschel survey of gas and dust in Protoplanetary Disks: Summary and Initial Statistics

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GASPS is a far-infrared line and continuum survey of protoplanetary and young debris disks using PACS on the Herschel Space Observatory. The survey includes [OI] at 63μm, as well as 70, 100 and 160μm continuum, with the brightest objects also studied in [OI]145μm, [CII]157μm, H_2O and CO. Targets included T Tauri stars and debris disks in 7 nearby young associations, and a sample of isolated Herbig AeBe stars. The aim was to study the global gas and dust content in a wide disk sample, systemically comparing the results with models. In this paper we review the main aims, target selection and observing strategy. We show initial results, including line identifications, sources detected, and a first statistical study. [OI]63μm was the brightest line in most objects, by a factor of $\sim$10. Detection rates were 49%, including 100% of HAeBe stars and 43% of T Tauri stars. Comparison with published dust masses show a dust threshold for [OI]63μm detection of $\sim 10^{-5}\ M_{\odot}$. Normalising to 140pc distance, 32% with mass 10^{-6}–$10^{-5}\ M_{\odot}$, and a small number with lower mass were also detected. This is consistent with moderate UV excess and disk flaring. In most cases, continuum and line emission is spatially and spectrally unresolved, suggesting disk emission. $\sim$10 objects were resolved, likely from outflows. Detection rates in [OI]145μm, [CII]157μm and CO J=18–17 were 20–40%, but [CII] was not correlated with disk mass, suggesting it arises instead from a compact envelope. [OI] detection rates in T Tauri associations of ages 0.3–4Myr were $\sim$50%. $\sim$2 stars were detectable in associations of 5–20Myr, with no detections in associations of age >20Myr. Comparing with the total number of young stars, and assuming a ISM-like gas/dust ratio, this indicates that $\sim$18% of stars retain a gas-rich disk of total mass $>1 M_{\mathrm{Jupiter}}$ for 1–4Myr, 1–7% keep such disks for 5–10Myr, and none remain beyond 10–20Myr.

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Planetesimal formation via sweep-up growth at the inner edge of dead zones

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The early stages of planet formation are still not well understood. Coagulation models have revealed numerous obstacles to the dust growth, such as the bouncing, fragmentation and radial drift barriers. We study the interplay between dust coagulation and drift in order to determine the conditions in protoplanetary disk that support the formation of planetesimals. We focus on planetesimal formation via sweep-up and investigate whether it can take place in a realistic protoplanetary disk. We have developed a new numerical model that resolves spatial distribution of dust in the radial and vertical dimension. The model uses representative particles approach to follow the dust evolution in protoplanetary disk. The coagulation and fragmentation of solids is taken into account using Monte Carlo method. A collision model adopting the mass transfer effect, that can occur for different-sized dust aggregate collisions, is implemented. We focus on a protoplanetary disk including a pressure bump caused by a steep decline of turbulent viscosity around the snow line. Our results show that sufficient resolution of the vertical disk structure in dust coagulation codes is necessary to obtain adequately short growth timescales, especially in the case of a low turbulence region. We find that a sharp radial variation of the turbulence strength at the inner edge of dead zone promotes planetesimal formation in several ways. It provides a pressure bump that efficiently prevents the dust from drifting inwards. It also causes a radial variation in the size of aggregates at which growth barriers occur, favoring the growth of large aggregates via sweeping up of small particles. In our model, by employing an ad hoc alpha viscosity change near the snow line, it is possible to grow planetesimals by incremental growth on timescales of approximately 10^5 years.

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The compact, time-variable radio source projected inside W3(OH): Evidence for a Photoevaporated Disk?

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We present new Karl G. Jansky Very Large Array observations of the compact (∼0.05 arcsec), time-variable radio source projected near the center of the ultracompact HII region W3(OH). The analysis of our new data as well as of VLA archival observations confirms the variability of the source on timescales of years and for a given epoch indicates a spectral index of $\alpha = 1.3 \pm 0.3$ ($S_\nu \propto \nu^\alpha$). This spectral index and the brightness temperature of the source (∼6,500 K) suggest that we are most probably detecting partially optically thick free-free radiation. The radio source is probably associated with the ionizing star of W3(OH), but an interpretation in terms of an ionized stellar wind fails because the detected flux densities are orders of magnitude larger than expected. We discuss several scenarios and tentatively propose that the radio emission could arise in a static ionized atmosphere around a fossil photoevaporated disk.

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Time-monitoring Observations of the Ro-Vibrational Overtone CO bands in Young Stars

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We present near-IR spectra of a sample of T Tauri, Herbig Ae/Be, and FU Ori objects. Using the FSPEC instrument on the Bok 90-inch telescope, we obtained K-band spectra with a resolution of ∼3500. Here we present spectra of the $\Delta v = 2$–0 and $\Delta v = 3$–1 bandheads of ro-vibrational transitions of carbon monoxide. We observed these spectra over multiple epochs spaced by a few days and approximately one month. Several of our targets show CO emission or absorption features. However we see little evidence of variability in these features across multiple epochs. We compare our results with previous observations, and discuss the physical implications of non-variable CO emission across the sampled timescales.

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A line confusion-limited millimeter survey of Orion KL. III. Sulfur oxide species

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We present a study of the sulfur-bearing species detected in a line confusion-limited survey towards Orion KL performed with the IRAM 30m telescope in the range 80–281 GHz. The study is part of an analysis of the line survey divided into families of molecules. Our aim is to derive accurate physical conditions and molecular abundances in the different components of Orion KL from observed SO and SO_2 lines. First we assumed LTE conditions obtain rotational temperatures. We then used a radiative transfer model, assuming either LVG or LTE excitation to derive column densities of these molecules in the different components of Orion KL. We have detected 68 lines of SO, ^{34}SO, ^{33}SO, and $S^{18}O$ and 653 lines of SO_2, $^{34}SO_2$, $^{33}SO_2$, $SO^{18}O$ and SO2 ν_2=1. We provide column densities for all of them and also upper limits for the column densities of $S^{17}O$, ^{36}SO, $^{34}S^{18}O$, $SO^{17}O$ and $^{34}SO_2$ ν_2=1 and for several undetected sulfur-bearing species. In addition, we present $2' \times 2'$ maps around Orion IRc2 of SO_2 transitions with energies from 19 to 131 K and also maps with four transitions of SO, ^{34}SO and $^{34}SO_2$. We observe an elongation of the gas along the NE-SW direction. An unexpected emission peak appears at 20.5 km s^{-1} in most lines of SO and SO_2. A study of the spatial distribution of this emission feature shows that it is a new component $\sim 5''$ in diameter, which lies $\sim 4''$ west of IRc2. We suggest the emission from this feature is related to shocks associated to the *BN* object. The highest column densities for SO and SO_2 are found in the high-velocity plateau (a region dominated by shocks) and in the hot core. These values are up to three orders of magnitude higher than the results for the ridge components. We also find high column densities for their isotopologues in both components. Therefore, we conclude that SO and SO_2 are good tracers, not only of regions affected by shocks, but also of regions with warm dense gas.

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Wave-like warp propagation in circumbinary discs I. Analytic theory and numerical simulations

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In this paper we analyse the propagation of warps in protostellar circumbinary discs. We use these systems as a test environment in which to study warp propagation in the bending-wave regime, with the addition of an external torque due to the binary gravitational potential. In particular, we want to test the linear regime, for which an analytic theory has been developed. In order to do so, we first compute analytically the steady state shape of an inviscid disc subject to the binary torques. The steady state tilt is a monotonically increasing function of radius, but misalignment is found at the disc inner edge. In the absence of viscosity, the disc does not present any twist. Then, we compare the time-dependent evolution of the warped disc calculated via the known linearised equations both with the analytic solutions and with full 3D numerical simulations. The simulations have been performed with the PHANTOM SPH code using 2 million particles. We find a good agreement both in the tilt and in the phase evo- lution for small inclinations, even at very low viscosities. Moreover, we have verified that the linearised equations are able to reproduce the diffusive behaviour when $\alpha > H/R$, where α is the disc viscosity parameter. Finally, we have used the 3D simulations to explore the non-linear regime. We observe a strongly non-linear behaviour, which leads to the breaking of the disc. Then, the inner disc starts precessing with its own precessional frequency. This behaviour has already been observed with numerical simulations in accretion discs around spinning black holes. The evolution of circumstellar accretion discs strongly depends on the warp evolution. Therefore the issue explored in this paper could be of fundamental importance in order to understand the evolution of accretion discs in crowded environments, when the gravitational interaction with other stars is highly likely, and in multiple systems. Moreover, the evolution of the angular momentum of the disc will affect the history of the angular momentum of forming planets.

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Herschel Reveals Massive Cold Clumps in NGC 7538

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We present the first overview of the *Herschel* observations of the nearby high-mass star-forming region NGC 7538, taken as part of the *Herschel* imaging study of OB Young Stellar objects (HOBYS) Key Programme. These PACS and SPIRE maps cover an approximate area of one square degree at five submillimeter and far-infrared wavebands. We have identified 780 dense sources and classified 224 of those. With the intention of investigating the existence of cold massive starless or class 0-like clumps that would have the potential to form intermediate- to high-mass stars, we further isolate 13 clumps as the most likely candidates for followup studies. These 13 clumps have masses in excess of 40 $M_\odot$ and temperatures below 15 K. They range in size from 0.4 pc to 2.5 pc and have densities between 3×10^3 cm^{-3} to 4×10^4 cm^{-3}. Spectral energy distributions are then used to characterize their energetics and evolutionary state through a luminosity-mass diagram. NGC 7538 has a highly filamentary structure, previously unseen in the dust continuum of existing submillimeter surveys. We report the most complete imaging to date of a large, evacuated ring of material in NGC 7538 which is bordered by many cool sources.

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Characterization of the MALT90 Survey and the Mopra Telescope at 90 GHz

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We characterize the Millimeter Astronomy Legacy Team 90 GHz (MALT90) Survey and the Mopra telescope at 90 GHz. We combine repeated position-switched observations of the source G300.968+01.145 with a map of the same source in order to estimate the pointing reliability of the position-switched observations and, by extension, the MALT90 survey; we estimate our pointing uncertainty to be 8 . We model the two strongest sources of systematic gain variability as functions of elevation and time-of-day and quantify the remaining absolute flux uncertainty. Corrections based on these two variables reduce the scatter in repeated observations from 12-25% down to 10-17%. We find no evidence for intrinsic source variability in G300.968+01.145. For certain applications, the corrections described herein will be integral for improving the absolute flux calibration of MALT90 maps and other observations using the Mopra telescope at 90 GHz.

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Improved angular momentum evolution model for solar-like stars

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Understanding the origin and evolution of stellar angular momentum is one of the major challenges of stellar physics. We present new models for the rotational evolution of solar-like stars between 1 Myr and 10 Gyr with the aim of reproducing the distributions of rotational periods observed for star forming regions and young open clusters within this age range.The models include a new wind braking law based on recent numerical simulations of magnetized stellar winds and specific dynamo and mass-loss prescriptions are adopted to tie angular momentum loss to angular velocity. The models additionally assume constant angular velocity during the disk accretion phase and allow for decoupling between the radiative core and the convective envelope as soon as the former develops. We have developed rotational evolution models for slow, median, and fast rotators with initial periods of 10, 7, and 1.4d, respectively. The models reproduce reasonably well the rotational behavior of solar-type stars between 1 Myr and 4.5 Gyr, including pre-main sequence (PMS) to zero-age main sequence (ZAMS) spin up, prompt ZAMS spin down, and the early-main sequence (MS) convergence of surface rotation rates. We find the model parameters accounting for the slow and median rotators are very similar to each other, with a disk lifetime of 5 Myr and a core-envelope coupling timescale of 28-30 Myr. In contrast, fast rotators have both shorter disk lifetimes (2.5 Myr) and core-envelope coupling timescales (12 Myr). We show that a large amount of angular momentum is hidden in the radiative core for as long as 1 Gyr in these models and we discuss the implications for internal differential rotation and lithium depletion. We emphasize that these results are highly dependent on the adopted braking law. We also report a tentative correlation between the initial rotational period and disk lifetime, which suggests that protostellar spin down by massive disks in the embedded phase is at the origin of the initial dispersion of rotation rates in young stars.We conclude that this class of semi-empirical models successfully grasp the main trends of the rotational behavior of solar-type stars as they evolve and make specific predictions that may serve as a guide for further development.

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Magnetically Active Stars in Taurus-Auriga: Activity and Rotation

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A sample of 70 magnetically active stars toward the Taurus-Auriga star-forming region has been investigated. The positions of the sample stars on the Rossby diagram have been analyzed. All stars are shown to be in the regime of a saturated dynamo, where the X-ray luminosity reaches its maximum and does not depend on the Rossby number. A correlation has been found between the lithium line equivalent width and the age of a solar-mass (from 0.7 to 1.2 Msun) pre-main-sequence star. The older the age, the smaller the Li line equivalent width. Analysis of the long-term photometric variability of these stars has shown that the photometric activity of the youngest stars is appreciably higher than that of the older objects from the sample. This result can be an indirect confirmation of the evolution of the magnetic field in pre-main-sequence stars from predominantly dipole and axisymmetric to multipole and nonaxisymmetric.

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The protoplanetary disks in the nearby massive star forming region Cygnus OB2

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The formation of stars in massive clusters is one of the main modes of the star formation process. However, the study of massive star forming regions is hampered by their typically large distances to the Sun. One exception to this is the massive star forming region Cygnus OB2 in the Cygnus X region, at the distance of about 1400 pc. Cygnus OB2 hosts very rich populations of massive and low-mass stars, being the best target in our Galaxy to study the formation of stars, circumstellar disks, and planets in presence of massive stars. In this paper we combine a wide and deep set of photometric data, from the r band to 24 μm, in order to select the disk bearing population of stars in Cygnus OB2 and identify the class I, class II, and stars with transition and pre-transition disks. We selected 1843 sources with infrared excesses in an area of $1^\circ \times 1^\circ$ centered on Cyg OB2 in several evolutionary stages: 8.4% class I, 13.1% flat-spectrum sources, 72.9% class II, 2.3% pre-transition disks, and 3.3% transition disks. The spatial distribution of these sources shows a central cluster surrounded by a annular overdensity and some clumps of recent star formation in the outer region. Several candidate subclusters are identified, both along the overdensity and in the rest of the association.

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Star formation with disc accretion and rotation I. Stars between 2 and 22 Msol at solar metallicity

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The way angular momentum is built up in stars during their formation process may have an impact on their further evolution. In the frame of the cold disc accretion scenario, we study for the first time how angular momentum builds up inside the star during its formation and what are the consequences for its evolution on the main sequence (MS). Computation begins from a hydrostatic core on the Hayashi line of 0.7 $M_\odot$ at solar metallicity (Z=0.014) rotating as a solid body. Accretion rates depending on the luminosity of the accreting object are considered varying between 1.5×10^{-5} and 1.7×10^{-3} $M_\odot$ yr^{-1}. The accreted matter is assumed to have an angular velocity equal to that of the outer layer of the accreting star. Models are computed for a mass-range on the zero-age main sequence (ZAMS) between 2 and 22 $M_\odot$. We study how the internal and surface velocities vary as a function of time during the accretion phase and the evolution towards the ZAMS. Stellar models, whose evolution has been followed along the pre-MS phase, are found to exhibit a shallow gradient of angular velocity on the ZAMS. Interestingly, for masses on the ZAMS larger than 8 $M_\odot$, there exists a maximum surface velocity that can be reached through the present scenario of formation. Typically, for 14 $M_\odot$ models, only stars with surface velocities on the ZAMS lower than about 45% of the critical velocity can be formed. To reach higher velocities would require to start from cores rotating above the critical limit. We find that this upper velocity limit is smaller for higher masses. In contrast, below 8 $M_\odot$, there is no restriction and the whole domain of velocities, up to the critical one, can be reached.

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An Enhanced Spectroscopic Census of the Orion Nebula Cluster

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We report new spectral types or spectral classification constraints for over 600 stars in the Orion Nebula Cluster (ONC) based on medium resolution ($R \approx 1500 - 2000$) red optical spectra acquired using the Palomar 200" and Kitt Peak 3.5m telescopes. Spectral types were initially estimated for F, G, and early K stars from atomic line indices while for late K and M stars, constituting the majority of our sample, indices involving TiO and VO bands were used. To ensure proper classification, particularly for reddened, veiled, or nebula-contaminated stars, all spectra were then visually examined for type verification or refinement. We provide an updated spectral type table that supersedes Hillenbrand (1997), increasing the percentage of optically visible ONC stars with spectral type information from 68% to 90%. However, for many objects, repeated observations have failed to yield spectral types primarily due to the challenges of adequate sky subtraction against a bright and spatially variable nebular background. The scatter between our new and our previously determined spectral types is approximately 2 spectral sub-classes. We also compare our grating spectroscopy results with classification based on narrow-band TiO filter photometry from da Rio et al. (2010, 2012), finding similar scatter. While the challenges of working in the ONC may explain much of the spread, we highlight several stars showing significant and unexplained bona fide spectral variations in observations taken several years apart; these and similar cases could be due to a combination of accretion and extinction changes. Finally, nearly 20% of ONC stars exhibit obvious Ca II triplet emission indicative of strong accretion.

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http://www.astro.caltech.edu/~lah/papers/OrionPaper.pdf
(note: preprint includes one long table, the electronic version of which will be available via the AJ)

Condition for the formation of micron-sized dust grains in dense molecular cloud cores

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We investigate the condition for the formation of micron-sized grains in dense cores of molecular clouds. This is motivated by the detection of the mid-infrared emission from deep inside a number of dense cores, the so-called 'coreshine,' which is thought to come from scattering by micron-sized grains. Based on numerical calculations of coagulation starting from the typical grain size distribution in the diffuse interstellar medium, we obtain a conservative lower limit to the time t to form micron-sized grains: $t/t_{\rm ff} > 3(5/S)(n_{\rm H}/10^5{\rm cm}^{-3})^{-1/4}$ (where $t_{\rm ff}$ is the free-fall time at hydrogen number density $n_{\rm H}$ in the core, and S the enhancement factor to the grain-grain collision cross-section to account for non-compact aggregates). At the typical core density $n_{\rm H} = 10^5{\rm cm}^{-3}$, it takes at least a few free-fall times to form the micron-sized grains responsible for coreshine. The implication is that those dense cores observed in coreshine are relatively long-lived entities in molecular clouds, rather than dynamically transient objects that last for one free-fall time or less.

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Interstellar H_2O Masers from J Shocks

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We present a model in which the 22 GHz H_2O masers observed in star-forming regions occur behind shocks propagating in dense regions (preshock density $n_0 \sim 10^6 - 10^8$ cm^{-3}). We focus on high-velocity ($v_s \gtrsim 30$ km s^{-1}) dissociative J shocks in which the heat of H_2 re-formation maintains a large column of $\sim 300 - 400$ K gas; at these temperatures the chemistry drives a considerable fraction of the oxygen not in CO to form H_2O. The H_2O column densities, the hydrogen densities, and the warm temperatures produced by these shocks are sufficiently high to enable powerful maser action. The observed brightness temperatures (generally $\sim 10^{11} - 10^{14}$ K) are the result of coherent velocity regions that have dimensions in the shock plane that are 10 to 100 times the shock thickness of $\sim 10^{13}$ cm. The masers are therefore beamed towards the observer, who typically views the shock "edge-on", or perpendicular to the shock velocity; the brightest masers are then observed with the lowest line of sight velocities with respect to the ambient gas. We present numerical and analytic studies of the dependence of the maser inversion, the resultant brightness temperature, the maser spot size and shape, the isotropic luminosity, and the maser region magnetic field on the shock parameters and the coherence path length; the overall result is that in galactic H_2O 22 GHz masers these observed parameters can be produced in J shocks with $n_0 \sim 10^6 - 10^8$ cm^{-3} and $v_s \sim 30 - 200$ km s^{-1}. A number of key observables such as maser shape, brightness temperature, and global isotropic luminosity depend only on the particle flux into the shock, $j = n_0 v_s$, rather than on n_0 and v_s separately.

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HARPS spectropolarimetry of Herbig Ae/Be stars

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Our knowledge of the presence and the strength of magnetic fields in intermediate-mass pre-main-sequence stars remains very poor. We present new magnetic field measurements in six Herbig Ae/Be stars observed with HARPS in spectropolarimetric mode. We downloaded from the European Southern Observatory (ESO) archive the publically available HARPS spectra for six Herbig Ae/Be stars. Wavelength shifts between right- and left-hand side circularly polarised spectra were interpreted in terms of a longitudinal magnetic field $\langle B_{\rm z}\rangle$, using the moment technique introduced by Mathys. The application of the moment technique to the HARPS spectra allowed us in addition to study the presence of the crossover effect and quadratic magnetic fields. Our search for longitudinal magnetic fields resulted in first detections of weak magnetic fields in the Herbig Ae/Be stars HD 58647 and HD 98922. Further, we confirm the previous tentative detection of a weak magnetic field in HD 104237 by Donati et al. and confirm the previous detection of a magnetic field in the Herbig Ae star HD 190073. Surprisingly, the measured longitudinal magnetic field of HD 190073, $\langle B_z \rangle = 91 \pm 18$ G at a significance level of 5σ is not in agreement with the measurement results of Alecian et al. (2013), $\langle B_z \rangle = -10 \pm 20$ G, who applied the LSD method to exactly the same data. No crossover effect was detected for any star in the sample. Only for HD 98922 the crossover effect was found to be close to 3σ with a measured value of -4228 ± 1443 km s^{-1} G. A quadratic magnetic field of the order of 10 kG was detected in HD 98922, and of $\sim$3.5 kG in HD 104237.

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The SEEDS Direct Imaging Survey for Planets and Scattered Dust Emission in Debris Disk Systems

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Debris disks around young main-sequence stars often have gaps and cavities which for a long time have been interpreted as possibly being caused by planets. In recent years, several giant planet discoveries have been made in systems hosting disks of precisely this nature, further implying that interactions with planets could be a common cause of such disk structures. As part of the SEEDS high-contrast imaging survey, we are surveying a population of debris disk-hosting stars with gaps and cavities implied by their spectral energy distributions, in order to attempt to spatially resolve the disk as well as to detect any planets that may be responsible for the disk structure. Here we report on intermediate results from this survey. Five debris disks have been spatially resolved, and a number of faint point sources have been discovered, most of which have been tested for common proper motion, which in each case has excluded physical companionship with the target stars. From the detection limits of the 50 targets that have been observed, we find that beta Pic b-like planets ($\sim$10 $M_{\rm jup}$ planets around G–A-type stars) near the gap edges are less frequent than 15–30%, implying that if giant planets are the dominant cause of these wide (27 AU on average) gaps, they are generally less massive than beta Pic b.

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Hydroxyl, water, ammonia, carbon monoxide and neutral carbon towards the Sgr A complex. VLA, Odin and SEST observations

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The Sagittarius A complex in the Galactic centre comprises an ensemble of molecular clouds of different species with a variety of geometrical and kinematic properties. This work aims to study molecular abundances, morphology, and kinematics by comparing hydroxyl, water, carbon monoxide, ammonia and atomic carbon and some of their isotopologues, in the +50 km s^{-1} cloud, the circumnuclear disk (CND), the +20 km s^{-1} cloud, the expanding molecular ring and the line-of-sight spiral arm features, including the Local/Sgr arm, the -30 km s^{-1} arm, and the 3-kpc arm. We observed the +50 km s^{-1} cloud, the CND and the +20 km s^{-1} cloud, and other selected positions at the Galactic centre with the VLA, and the Odin satellite. The VLA was used to map the 1665 and 1667 MHz OH lambda doublet main lines of the ($^2\Pi_{3/2}$) state, and the Odin satellite was used to map the 557 GHz H_2O ($1_{10}-1_{01}$) line as well as to observe the 548 GHz $H_2^{18}O$ ($1_{10}-1_{01}$) line, the 572 GHz NH_3 (1_0-0_0) line, the 576 GHz CO $J=5-4$ line and the 492 GHz C I ($^3P_1$ -$^3P_0$) line. Furthermore, the SEST was used to map a $4'.5\times 6'$ region of the Sgr A complex in the 220 GHz $C^{18}O$ $J=2-1$ line.
Strong OH absorption, H_2O emission and absorption lines were seen at all observed positions, and the $H_2^{18}O$ line was detected in absorption towards the +50 km s^{-1} cloud, the CND, the +20 km s^{-1}cloud, the expanding molecular ring, and the 3-kpc arm. Strong CO J= $5-4$, $C^{18}O$ $J=2-1$, and neutral carbon C I emissions were seen towards the +50 and +20 km s^{-1} clouds. NH_3 was only detected in weak absorption originating in the line-of-sight spiral arm features. The abundances of OH and H_2O in the +50 and +20 km s^{-1} clouds reflect the different physical environments in the clouds, where shocks and star formation prevail in the +50 km s^{-1} cloud and giving rise to a higher rate of H_2O production there than in the +20 km s^{-1} cloud. In the CND, cloud collisions and shocks are frequent, and the CND is also subject to intense UV-radiation emanating from the supermassive black hole and the central star cluster. The CND is rich in H_2O and OH, and these abundances are considerably higher than in the +50 and +20 km s^{-1} clouds. We compare our estimated abundances of OH, H_2O, and NH_3 with similar and differing results for some other sources available in the literature. As compared to the quiescent cloud values of a few x 10^{-9}, or lower, the H_2O abundance

is markedly enhanced in the front sides of the Sgr A molecular cloud cores, (2-7)$\times10^{-8}$, as observed in absorption, and highest in the CND. A similar abundance enhancement is seen in OH. The likely explanation is PDR chemistry including grain surface reactions, and perhaps also the influence of shocks. In the redward high-velocity line wings of the +50 and +20km s^{-1} clouds and the CND, the H_2O abundances are estimated to be (1-6)$\times10^{-6}$ or higher, i.e., similar to the water abundances in outflows of the Orion KL and DR21 molecular clouds, which are said to be caused by the combined action of shock desorption from icy grain mantles and high-temperature, gas-phase shock chemistry.

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Ionization driven molecular outflow in K3-50A

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Whether high mass stars continue to accrete material beyond the formation of an HII region is still an open question. Ionized infall and outflow have been seen in some sources, but their ties to the surrounding molecular gas are not well constrained. We aim to quantify the ionized and molecular gas dynamics in a high mass star forming region (K3-50A) and their interaction. We present CARMA observations of the 3mm continuum, H41α, and HCO^+ emission, and VLA continuum observations at 23 GHz and 14.7 GHz to quantify the gas and its dynamics in K3-50A. We find large scale dynamics consistent with previous observations. On small scales, we find evidence for interaction between the ionized and molecular gas which suggests the ionized outflow is entraining the molecular one. This is the first time such an outflow entrained by photo ionized gas has been observed. Accretion may be ongoing in K3-50A because an ionized bipolar outflow is still being powered, which is in turn entraining part of the surrounding molecular gas. This outflow scenario is similar to that predicted by ionization feedback models.

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Streaming instability in the quasi-global protoplanetary disks

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We investigate streaming instability using two-fluid approximation (neutral gas and dust) in a quasi-global, unstratified protoplanetary disk, with the help of PIERNIK code. We compare amplification rate of the eigen-mode in numerical simulations, with the corresponding growth resulting from the linear stability analysis of full system of Euler's equation including aerodynamic drag. Following Youdin & Goodman (2005) we show that (1) rapid dust clumping occurs due to the difference in azimuthal velocities of gas and dust, coupled by the drag force, (2) initial density perturbations are amplified by several orders of magnitude. We demonstrate that the multi-fluid extension of the simple and efficient Relaxing TVD scheme, implemented in PIERNIK, leads to results, which are compatible with those obtained with other methods.

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The Curious Case of Glass I: High Ionization and Variability of Different Types

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Our Spitzer IRS observation of the infrared companion Glass Ib revealed fine structure emission with high ionization ([NeIII]/[NeII]=2.1 and [SIV]/[SIII]=0.6) that indicates the gas is likely illuminated by hard radiation. While models suggest extreme ultraviolet radiation could be present in T Tauri stars (Hollenbach & Gorti 2009 and references therein), this is the first detection of [SIV] and such a high [NeIII]/[NeII] ratio in a young star. We also find that Glass Ib displays the molecules HCN, CO_2, and H_2O in emission. Here we investigate the Glass I binary system and consider possible mechanisms that may have caused the high ionization, whether from an outflow or disk irradiation. We also model the spectral energy distributions of Glass Ia and Ib to test if the system is a young member of the Chameleon I star-forming region, and consider other possible classifications for the system. We find Glass Ib is highly variable, showing changes in continuum strength and emission features at optical, near-infrared, and mid-infrared wavelengths. The optical light curve indicates that a central stellar component in Glass Ib became entirely visible for 2.5 years beginning in mid-2002, and that possibly displayed periodic variability with repeated, short-period dimming during that time. As the fine structure emission was not detected in observations before or after our Spitzer IRS observation, we explore whether the variable nature of Glass Ib is related to the gas being highly ionized, possibly due to variable accretion or an X-ray flare.

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An interferometric study of the Fomalhaut inner debris disk. III. Detailed models of the exozodiacal disk and its origin

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Debris disks are thought to be extrasolar analogs to the solar system planetesimal belts. The star Fomalhaut harbors a cold debris belt at 140 AU comparable to the Edgeworth-Kuiper belt, as well as evidence of a warm dust component, unresolved by single-dish telescopes, which is suspected of being a bright analog to the solar system's zodiacal dust.
Interferometric observations obtained with the VLTI/VINCI instrument and the Keck Interferometer Nuller have identified near- and mid-infrared excesses attributed respectively to hot and warm exozodiacal dust residing in the inner few AU of the Fomalhaut environment. We aim to characterize the properties of this double inner dust belt and to unveil its origin.
We performed parametric modeling of the exozodiacal disk ("exozodi") using the GRaTeR radiative transfer code to reproduce the interferometric data, complemented by mid- to far-infrared photometric measurements from *Spitzer* and *Herschel*. A detailed treatment of sublimation temperatures was introduced to explore the hot population at the size-dependent sublimation rim. We then used an analytical approach to successively testing several source mechanisms for the dust and suspected parent bodies.
A good fit to the multiwavelength data is found by two distinct dust populations: (1) a population of very small (0.01 to 0.5 μm), hence unbound, hot dust grains confined in a narrow region ($\sim$0.1 – 0.3 AU) at the sublimation rim of carbonaceous material; (2) a population of bound grains at $\sim$ 2AU that is protected from sublimation and has a higher mass despite its fainter flux level. We propose that the hot dust is produced by the release of small carbon grains following the disruption of dust aggregates that originate from the warm component. A mechanism, such as gas braking, is required to further confine the small grains for a long enough time. *In situ* dust production could hardly be ensured for the age of the star, so we conclude that the observed amount of dust is triggered by intense dynamical activity.
Fomalhaut may be representative of exozodis that are currently being surveyed at near and mid-infrared wavelengths worldwide. We propose a framework for reconciling the "hot exozodi phenomenon" with theoretical constraints: the hot component of Fomalhaut is likely the "tip of the iceberg" since it could originate from the more massive, but fainter, warm dust component residing near the ice line. This inner disk exhibits interesting morphology and can be considered a prime target for future exoplanet research.

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Earliest Stages of Protocluster Formation: Substructure and Kinematics of Starless Cores in Orion

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We study the structure and kinematics of nine 0.1 pc-scale cores in Orion with the IRAM 30-m telescope and at higher resolution eight of the cores with CARMA, using CS(2–1) as the main tracer. The single-dish moment zero maps of the starless cores show single structures with central column densities ranging from 7 to 42 $\times$ 10^{23} cm^{-2} and LTE masses from 20 $M_\odot$ to 154 $M_\odot$. However, at the higher CARMA resolution ($5''$), all of the cores except one fragment into 3–5 components. The number of fragments is small compared to that found in some turbulent fragmentation models, although inclusion of magnetic fields may reduce the predicted fragment number and improve the model agreement. This result demonstrates that fragmentation from parsec-scale molecular clouds to sub-parsec cores continues to take place inside the starless cores. The starless cores and their fragments are embedded in larger filamentary structures, which likely played a role in the core formation and fragmentation. Most cores show clear velocity gradients, with magnitudes ranging from 1.7 to 14.3 km s^{-1} pc^{-1}. We modeled one of them in detail, and found that its spectra are best explained by a converging flow along a filament toward the core center; the gradients in other cores may be modeled similarly. We infer a mass inflow rate of $\sim 2 \times 10^{-3}$ $M_\odot$ yr^{-1}, which is in principle high enough to overcome radiation pressure and allow for massive star formation. However, the core contains multiple fragments, and it is unclear whether the rapid inflow would feed the growth of primarily a single massive star or a cluster of lower mass objects. We conclude that fast, supersonic converging flow along filaments play an important role in massive star and cluster formation.

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Wave-like warp propagation in circumbinary discs II. Application to KH 15D

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KH 15D is a protostellar binary system that shows a peculiar light curve. In order to model it, a narrow circumbinary precessing disc has been invoked, but a proper dynamical model has never been developed. In this paper, we analytically address the issue of whether such a disc can rigidly precess around KH 15D, and we relate the precessional period to the main parameters of the system. Then, we simulate the disc s dynamics by using a 1D model developed in a companion paper (Facchini et al. 2013), such that the warp propagates into the disc as a bending wave, which is expected to be the case for protostellar discs. The validity of such an approach has been confirmed by comparing its results with full 3D SPH simulations on extended discs. In the present case, we use this 1D code to model the propagation of the warp in a narrow disc. If the inner truncation radius of the disc is set by the binary tidal torques at ~ 1 AU, we find that the disc should extend out to 6 -10 AU (depending on the models), and is therefore wider than previously suggested. Our simulations show that such a disc does reach an almost steady state, and then precesses as a rigid body. The disc displays a very small warp, with a tilt inclination that increases with radius in order to keep the disc in equilibrium against the binary torque. However, for such wider discs, the presence of viscosity leads to a secular decay of the tilt on a timescale of $\approx 3000(\alpha/0.05)^{-1}$ years, where α is the disc viscosity parameter. The presence of a third body (such as a planet), orbiting at roughly 10 AU might simultaneously explain the outer truncation of the disc and the maintenance of the tilt for a prolonged time.

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The photoevaporation of a neutral structure by an EUV+FUV radiation field

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The EUV photoionizing radiation and FUV dissociating radiation from newly born stars photoevaporate their parental neutral cloud, leading to the formation of dense clumps that could eventually form additional stars. We study the effects of including a photodissociating FUV flux in models of the fragmentation of a photoevaporating, self-gravitating molecular cloud. We compute 3D simulations of the interaction of an inhomogeneous, neutral, self-gravitating cloud with external EUV and FUV radiation fields, and calculate the number of collapsing clumps and their mass. We find that the presence of an outer photodissociation region has an important effect on the formation of dense structures due to the expansion of an HII region. In particular, including a FUV field leads to the earlier formation of a larger number of dense clumps, which might lead to the formation of more stars.

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Formation of circumbinary planets in a dead zone

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Circumbinary planets have been observed at orbital radii where binary perturbations may have significant effects on the gas disk structure, on planetesimal velocity dispersion, and on the coupling between turbulence and planetesimals. Here, we note that the impact of all of these effects on planet formation is qualitatively altered if the circumbinary disk structure is layered, with a non-turbulent midplane layer (dead zone) and strongly turbulent surface layers. For close binaries, we find that the dead zone typically extends from a radius close to the inner disk edge up to a radius of around 10–20 AU from the centre of mass of the binary. The peak in the surface density occurs within the dead zone, far from the inner disk edge, close to the snow line, and may act as a trap for aerodynamically coupled solids. We suggest that circumbinary planet formation may be easier near this preferential location than for disks around single stars. However, dead zones around wide binaries are less likely and hence planet formation may be more difficult there.

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Externally Fed Star Formation: A Numerical Exploration

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We investigate, through a series of numerical calculations, the evolution of dense cores that are accreting external gas up to and beyond the point of star formation. Our model clouds are spherical, unmagnetized configurations with fixed outer boundaries, across which gas enters subsonically. When we start with any near-equilibrium state, we find that the cloud's internal velocity also remains subsonic for an extended period, in agreement with observations. However, the velocity becomes supersonic shortly before the star forms. Consequently, the accretion rate building up the protostar is much greater than the benchmark value c_s^3/G, where c_s is the sound speed in the dense core. This accretion spike would generate a higher luminosity than those seen in even the most embedded young stars. Moreover, we find that the region of supersonic infall surrounding the protostar races out to engulf much of the cloud, again in violation of the observations, which show infall to be spatially confined. Similar problematic results have been obtained by all other hydrodynamic simulations to date, regardless of the specific infall geometry or boundary conditions adopted. Low-mass star formation is evidently a quasi-static process, in which cloud gas moves inward subsonically until the birth of the star itself. We speculate that magnetic tension in the cloud's deep interior helps restrain the infall prior to this event.

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The Monitor Project: Stellar rotation at 13 Myr: I. A photometric monitoring survey of the young open cluster h Per.

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We aim at constraining the angular momentum evolution of low mass stars by measuring their rotation rates when they begin to evolve freely towards the ZAMS, i.e. after the disk accretion phase has stopped. We conducted a multi-site photometric monitoring of the young open cluster h Persei that has an age of ∼13 Myr. The observations were done in the I-band using 4 different telescopes and the variability study is sensitive to periods from less than 0.2 day to 20 days. Rotation periods are derived for 586 candidate cluster members over the mass range $0.4 \leq M/M_{\odot} \leq 1.4$. The rotation period distribution indicates a sligthly higher fraction of fast rotators for the lower mass objects, although the lower and upper envelopes of the rotation period distribution, located respectively at ∼0.2-0.3d and ∼ 10d, are remarkably flat over the whole mass range. We combine this period distribution with previous results obtained in younger and older clusters to model the angular momentum evolution of low mass stars during the PMS. The h Per cluster provides the first statistically robust estimate of the rotational period distribution of solar-type and lower mass stars at the end of the PMS accretion phase (≥10 Myr). The results are consistent with models that assume significant core-envelope decoupling during the angular momentum evolution to the ZAMS.

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Luminosity of young Jupiters revisited. Massive cores make hot planets

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The intrinsic luminosity of young Jupiters is of high interest for planet formation theory. It is an observable quantity that is determined by important physical mechanisms during formation, namely the accretion shock structure, and even more fundamentally, the basic formation mechanism (core accretion or gravitational instability). We study the impact of the core mass on the post-formation entropy and luminosity of young giant planets forming via core accretion with a supercritical shock (cold accretion). For this, we conduct self-consistently coupled formation and evolution calculations of giant planets with masses between 1 and 12 Jovian masses and core masses between 20 and 120 Earth masses. We find that the post-formation luminosity of massive giant planets is very sensitive to the core mass. An increase of the core mass by a factor 6 results in an increase of the post-formation luminosity of a 10 Jovian mass planet by a factor 120. Due to this dependency, there is no single well defined post-formation luminosity for core accretion, but a wide range. For massive cores (∼100 Earth masses), the post-formation luminosities of core accretion planets become so high that they approach those in the hot start scenario that is often associated with gravitational instability. For the mechanism to work, it is necessary that the solids are accreted before or during gas runaway accretion, and that they sink deep into the planet. We make no claims whether or not such massive cores can actually form in giant planets. But if yes, it becomes difficult to rule out core accretion as formation mechanism based solely on luminosity for directly imaged planets that are more luminous than predicted for low core masses. Instead of invoking gravitational instability as the consequently necessary formation mode, the high luminosity could also be caused simply by a more massive core.

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Planet or Brown Dwarf? Inferring the Companion Mass in HD 100546 from the Wall Shape using Mid-Infrared Interferometry

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Giant planets form in protoplanetary disks while these disks are still gas-rich, and can reveal their presence through the annular gaps they carve out. HD 100546 is a gas-rich disk with a wide gap between between a radius of ∼1 and 13 AU, possibly cleared out by a planetary companion or planetary system. We want to identify the nature of the unseen companion near the far end of the disk gap. We use mid-infrared interferometry at multiple baselines to constrain the curvature of the disk wall at the far end of the gap. We use 2D hydrodynamical simulations of embedded planets and brown dwarfs to estimate viscosity of the disk and the mass of a companion close to the disk wall. We find that the disk wall at the far end of the gap is not vertical, but rounded-off by a gradient in the surface density. Such a gradient can be reproduced in hydrodynamical simulations with a single, heavy companion ($\gtrsim$30...80 $M_{\rm Jup}$) while the disk has viscosity of at least $\alpha \gtrsim 5 \cdot 10^{-3}$. Taking into account the changes in the temperature structure after gap opening reduces the lower limit on the planet mass and disk viscosity to 20 $M_{\rm Jup}$ and $\alpha = 2 \cdot 10^{-3}$). The object in the disk gap of HD 100546 that shapes the disk wall is most likely a $60^{+20}_{-40} M_{\rm Jup}$ brown dwarf, while the disk viscosity is estimated to be at least $\alpha = 2 \cdot 10^{-3}$. The disk viscosity is an important factor in estimating planetary masses from disk morphologies: more viscous disks need heavier planets to open an equally deep gap.

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A bright-rimmed cloud sculpted by the HII region Sh2-48

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To characterize a bright-rimmed cloud embedded in the HII region Sh2-48 searching for evidence of triggered star formation. We carried out observations towards a region of $2' \times 2'$ centered at RA=$18^{\rm h}$ $22^{\rm m}$ $11.39^{\rm s}$, dec.=$-14°$ $35'$ $24.81''$ (J2000) using the Atacama Submillimeter Telescope Experiment (ASTE; Chile) in the ^{12}CO J=3–2,^{13}CO J=3–2, HCO$^+$ J=4–3, and CS J=7–6 lines with an angular resolution of about $22''$. We also present radio continuum observations at 5 GHz carried out with the Jansky Very Large Array (JVLA; EEUU) interferometer with a synthetized beam of $7'' \times 5''$. The analysis of our molecular observations reveals the presence of a relatively dense clump with $n(H_2)$ $\sim 3 \times 10^3$ cm^{-3}, located in projection onto the interior of the HII region Sh2-48. The emission distribution of the four observed molecular transitions has, at V_{LSR} ∼38 km s^{-1}, morphological anti-correlation with the bright-rimmed cloud as seen in the optical emission. From the new radio continuum observations we identify a thin layer of ionized gas located at the border of the clump which is facing to the ionizing star. The ionized gas has an electron density of about 73 cm^{-3} which supports the hypothesis that the clump is being photoionized by the nearby star, BD-14 5014. From the evaluation of the pressure balance between the ionized and molecular gas, we conclude that the clump would be in a pre-pressure balance state with the shocks being driven into the surface layer. Two YSO candidates (class I), are placed slightly beyond the bright rim suggesting that their formation could have been triggered via the radiation-driven implosion process.

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A near-infrared variability campaign of TMR-1: New light on the nature of the candidate protoplanet TMR-1C

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We present a near-infrared (NIR) photometric variability study of the candidate protoplanet, TMR-1C, located at a separation of about 10″ (∼1000 AU) from the Class I protobinary TMR-1AB in the Taurus molecular cloud. Our campaign was conducted between October, 2011, and January, 2012. We were able to obtain 44 epochs of observations in each of the H and K_s filters. Based on the final accuracy of our observations, we do not find any strong evidence of short-term NIR variability at amplitudes of >0.15–0.2 mag for TMR-1C or TMR-1AB. Our present observations, however, have reconfirmed the large-amplitude long-term variations in the NIR emission for TMR-1C, which were earlier observed between 1998 and 2002, and have also shown that no particular correlation exists between the brightness and the color changes. TMR-1C became brighter in the H-band by ∼1.8 mag between 1998 and 2002, and then fainter again by ∼0.7 mag between 2002 and 2011. In contrast, it has persistently become brighter in the K_s-band in the period between 1998 and 2011. The $(H - K_s)$ color for TMR-1C shows large variations, from a red value of 1.3±0.07 and 1.6±0.05 mag in 1998 and 2000, to a much bluer color of −0.1±0.5 mag in 2002, and then again a red color of 1.1±0.08 mag in 2011. The observed variability from 1998 to 2011 suggests that TMR-1C becomes fainter when it gets redder, as expected from variable extinction, while the brightening observed in the K_s-band could be due to physical variations in its inner disk structure. The NIR colors for TMR-1C obtained using the high precision photometry from 1998, 2000, and 2011 observations are similar to the protostars in Taurus, suggesting that it could be a faint dusty Class I source. Our study has also revealed two new variable sources in the vicinity of TMR-1AB, which show long-term variations of ∼1–2 mag in the NIR colors between 2002 and 2011. (abridged)

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X-ray embedded stars as driving sources of outflow-driven turbulence in OMC1-S

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Outflows arising from very young stars affect their surroundings and influence the star formation in the parental core. Multiple molecular outflows and Herbig-Haro (HH) objects have been observed in Orion, many of them originating from the embedded massive star-forming region known as OMC1-S. The detection of the outflow driving sources is commonly difficult, because they are still hidden behind large extinction, preventing their direct observation at optical and even near and mid-IR wavelengths. With the aim of improving the identification of the driving sources of the multiple outflows detected in OMC1-S, we used the catalog provided by deep X-ray observations, which have unveiled the very embedded population of pre-main sequence stars. We compared the position of stars observed by the Chandra Orion Ultra Deep project (COUP) in OMC1-S with the morphology of the molecular outflows and the directions of measured proper motions of HH optical objects. We find that 6 out of 7 molecular outflows reported in OMC1-S (detection rate of 86%) have an extincted X-ray COUP star located at the expected position of the driving source. In several cases, X-rays detected the possible driving sources for the first time. This clustered embedded population revealed by Chandra is very young, with an estimated average age of few 10^5 yr. It is also likely responsible for the multiple HH objects, which are the optical correspondence of flows arising from the cloud. We show that the molecular outflows driven by the members of the OMC1-S cluster can account for the observed turbulence at core-scales and

regulate the star formation efficiency. We discuss the effects of outflow feedback in the formation of massive stars, concluding that the injected turbulence in OMC1-S is compatible with a competitive accretion scenario.

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A Spatially Resolved Vertical Temperature Gradient in the HD 163296 Disk

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We analyze sensitive, sub-arcsecond resolution ALMA Science Verification observations of CO emission lines in the protoplanetary disk hosted by the young, isolated Ae star HD 163296. The observed spatial morphology of the ^{12}CO J=3-2 emission line is asymmetric across the major axis of the disk; the ^{12}CO J=2-1 line features a much less pronounced, but similar, asymmetry. The J=2-1 emission from ^{12}CO and its main isotopologues have no resolved spatial asymmetry. We associate this behavior as the direct signature of a vertical temperature gradient and layered molecular structure in the disk. This is demonstrated using both toy models and more sophisticated calculations assuming non-local thermodynamic equilibrium (non LTE) conditions. A model disk structure is developed to reproduce both the distinctive spatial morphology of the ^{12}CO J=3-2 line as well as the J=2-1 emission from the CO isotopologues assuming relative abundances consistent with the interstellar medium. This model disk structure has $\tau = 1$ emitting surfaces for the ^{12}CO emission lines that make an angle of about 15 degrees with respect to the disk midplane. Furthermore, we show that the spatial and spectral sensitivity of these data can distinguish between models that have sub-Keplerian gas velocities due to the vertical extent of the disk and its associated radial pressure gradient (a fractional difference in the bulk gas velocity field of approximately greater than 5

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Astrometric orbit of a low-mass companion to an ultracool dwarf

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Little is known about the existence of extrasolar planets around ultracool dwarfs. Furthermore, binary stars with Sun-like primaries and very low-mass binaries composed of ultracool dwarfs show differences in the distributions of mass ratio and orbital separation that can be indicative of distinct formation mechanisms. Using FORS2/VLT optical imaging for high precision astrometry we are searching for planets and substellar objects around these dwarfs to investigate their multiplicity properties for very low companion masses. Here we report astrometric measurements with an accuracy of two tenths of a milli-arcsecond over two years that reveal orbital motion of the nearby L1.5 dwarf DENIS-P J082303.1-491201 located at 20.77 ± 0.08 pc caused by an unseen companion that revolves about its host on an eccentric orbit in 246.4 ± 1.4 days. We estimate the L1.5 dwarf to have 7.5 ± 0.7 % of the Sun's mass, which implies a companion mass of 28 ± 2 Jupiter masses. This new system has the lowest mass ratio (0.36 ± 0.02) of known very low-mass binaries with characterised orbits. With this discovery we demonstrate 200 micro-arcsecond astrometry over an arc-minute field and over several years that is sufficient for discovering sub-Jupiter mass planets around ultracool dwarfs. We also show that the achieved parallax accuracy of < 0.4 % makes it possible to remove distance as a dominant source of uncertainty in the modelling of ultracool dwarfs.

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Photometric and spectroscopic variability of the FUor star V582 Aurigae

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We present results from optical photometric and spectroscopic observations of the eruptive pre-main sequence star V582 Aur. Variability of the star was reported a few years ago when it was suspected as a possible FU Orionis object. Due to the small number of currently known FUors, a new object of this type is ideal target for follow-up photometric and spectroscopic observations. We carried out BVRI CCD photometric observations in the field of V582 Aur from 2009 August to 2013 February. We acquired high-, medium-, and low-resolution spectroscopy of V582 Aur during this period. To study the pre-outburst variability of the target and construct its historical light curve, we searched for archival observations in photographic plate collections. Both CCD and photographic observations were analyzed using a sequence of 14 stars in the field of V582 Aur calibrated in BVRI. The pre-outburst photographic observations of V582 Aur show low-amplitude light variations typical of T Tauri stars. Archival photographic observations indicate that the increase in brightness began in late 1984 or early 1985 and the star reached the maximum level of brightness at 1986 January. The spectral type of V582 Aur can be defined as G0I with strong P Cyg profiles of Hα and Na I D lines, which are typical of FU Orionis objects. Our BVRI photometric observations show large amplitude variations ($\Delta V \sim 2.8$ mag.) during the 3.5 year period of observations. Most of the time, however, the star remains in a state close to the maximum brightness. The deepest drop in brightness was observed in the spring of 2012, when the brightness of the star fell to a level close to the pre-outburst. The multicolor photometric data show a color reversal during the minimum in brightness, which is typical of UX Ori variables. The corresponding spectral observations show strong variability in the profiles and intensities of the spectral lines (especially Hα), which indicate significant changes in the accretion rate. On the basis of photometric monitoring performed over the past three years, the spectral properties of the maximal light, and the shape of the long-term light curve, we confirm the affiliation of V582 Aur to the group of FU Orionis objects.

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No evidence for intense, cold accretion onto YSOs from measurements of Li in T-Tauri stars

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We have used medium resolution spectra to search for evidence that proto-stellar objects accrete at high rates during their early 'assembly phase'. Models predict that depleted lithium and reduced luminosity in T-Tauri stars are key signatures of 'cold' high-rate accretion occurring early in a star's evolution.
We found no evidence in 168 stars in NGC 2264 and the Orion Nebula Cluster for strong lithium depletion through analysis of veiling corrected 6708 Å lithium spectral line strengths. This suggests that 'cold' accretion at high rates ($\dot{M} \geq 5 \times 10^{-4}$ M$_\odot$ yr^{-1}) occurs in the assembly phase of fewer than 0.5 per cent of $0.3 \leq M_\star \leq 1.9\,M_\odot$ stars.
We also find that the dispersion in the strength of the 6708 Å lithium line might imply an age spread that is similar in magnitude to the apparent age spread implied by the luminosity dispersion seen in colour magnitude diagrams. Evidence for weak lithium depletion (< 10 per cent in equivalent width) that is correlated with luminosity is also apparent, but we are unable to determine whether age spreads or accretion at rates less than 5×10^{-4} M$_\odot$ yr^{-1} are

responsible.

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Masses and Distance of the Young Binary NTTS 045251+3016

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As part of our continuing campaign to measure the masses of pre-main sequence (PMS) stars dynamically and thus to assess the reliability of the discrepant theoretical calculations of contraction to the main sequence, we present new results for NTTS 045251+3016, a visual and double-lined spectroscopic binary in the Taurus-Star Forming Region (SFR). We obtained new high angular resolution astrometry and high spectral resolution spectroscopy at Keck Observatory. The new data lead to a significant revision of previously published orbital parameters. In particular, we find that the masses of the primary and secondary are 0.86 ± 0.11 and 0.55 ± 0.05 $M_\odot$, respectively, smaller than previously reported, and that the system lies 158.7 ± 3.9 pc from the sun, further than previously reported.

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Determination of the far-infrared dust opacity in a prestellar core

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We correlated near-infrared stellar H-Ks colour excesses of background stars from NTT/SOFI with the far-IR optical depth map, tauFIR, derived from Herschel 160, 250, 350, and 500 μm data. The Herschel maps were also used to construct a model for the cloud to examine the effect of temperature gradients on the estimated optical depths and dust absorption cross-sections. A linear correlation is seen between the colour H-Ks and tauFIR up to high extinctions (A_V $\sim$25). The correlation translates to the average extinction ratio $A_{250\mu\mathrm{m}}/A_J = 0.0014 \pm 0.0002$, assuming a standard near-infrared extinction law and a dust emissivity index β=2. Using an empirical N_H/A_J ratio we obtain an average absorption cross-section per H nucleus of $\sigma^{\mathrm{H}}_{250\mu\mathrm{m}} = (1.8 \pm 0.3) \times 10^{-25}$ cm^2 H-atom^{-1}, corresponding to a cross-section per unit mass of gas $\kappa^{\mathrm{G}}_{250\mu\mathrm{m}} = 0.08 \pm 0.01$ cm^2 g^{-1}. The cloud model however suggests that owing to the bias caused by temperature changes along the line-of-sight these values underestimate the true cross-sections by up to 40% near the centre of the core. Assuming that the model describes the effect of the temperature variation on tauFIR correctly, we find that the relationship between H-Ks and tauFIR agrees with the recently determined relationship between σ^{H} and N_H in Orion A. The derived far-IR cross-section agrees with previous determinations in molecular clouds with moderate column densities, and is not particularly large compared with some other cold cores. We suggest that this is connected to the core not being very dense (the central density is likely to be $\sim$$10^5$ cm^{-3}) and judging from previous

molecular line data, it appears to be at an early stage of chemical evolution. (abridged)

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A Semi-analytical Description for the Formation and Gravitational Evolution of Protoplanetary Disks

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We investigate the formation process of self-gravitating protoplanetary disks in unmagnetized molecular clouds. The angular momentum is redistributed by the action of gravitational torques in the massive disk during its early formation. We develop a simplified one-dimensional accretion disk model that takes into account the infall of gas from the envelope onto the disk and the transfer of angular momentum in the disk with an effective viscosity. First we evaluate the gas accretion rate from the cloud core onto the disk by approximately estimating the effects of gas pressure and gravity acting on the cloud core. We formulate the effective viscosity as a function of the Toomre Q parameter that measures the local gravitational stability of the rotating thin disk. We use a function for viscosity that changes sensitively with Q when the disk is gravitationally unstable. We find a strong self-regulation mechanism in the disk evolution. During the formation stage of protoplanetary disks, the evolution of the surface density does not depend on the other details of the modeling of effective viscosity, such as the prefactor of the viscosity coefficient. Next, to verify our model, we compare the time evolution of the disk calculated with our formulation with that of three-dimensional hydrodynamical simulations. The structures of the resultant disks from the one-dimensional accretion disk model agree well with those of the three-dimensional simulations. Our model is a useful tool for the further modeling of chemistry, radiative transfer, and planet formation in protoplanetary disks.

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Direct Imaging of a Compact Molecular Outflow from a Very Low-luminosity Object; L1521F-IRS

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Studying the physical conditions of very low-luminosity objects (VeLLOs; $L_{\rm bol} < 0.1$ $L_\odot$) is important for understanding the earliest evolutionary stage of protostars and brown dwarfs. We report interferometric observations of the VeLLO L1521F-IRS, in ^{12}CO (2–1) line emission and the 1.3 mm continuum emission, using the Submillimeter Array (SMA). With the ^{12}CO (2–1) high-resolution observations, we have spatially resolved a compact but poorly collimated molecular outflow associated with L1521F-IRS for the first time. The blueshifted and redshifted lobes are aligned along the east and west side of L1521F-IRS with a lobe size of ≈1000 AU. The estimated outflow mass, maximum outflow velocity, and outflow force are (9.0-80)$\times10^{-4}$ $M_\odot$, 7.2 km s^{-1}, and (7.4-66)$\times10^{-7}$ $M_\odot$ km s^{-1} yr^{-1}, respectively. The estimated outflow parameters such as size, mass, and momentum rate are similar to values derived for other VeLLOs, and are located at the lower end of values compared to previously studied outflows associated with low- to high-mass star forming regions. Low-velocity less collimated (1.5 km s^{-1}/1200 AU) and higher-velocity compact (4.0 km s^{-1}/920 AU) outflow components are suggested by the data. These velocity structures are not consistent with those expected in the jet driven or wind driven outflow models, perhaps suggesting a remnant outflow from the FHSC as well as an

undeveloped outflow from the protostar. Detection of an infrared source and compact millimeter continuum emission suggest the presence of the protostar, while its low bolometric luminosity (0.034–0.07 $L_\odot$), and small outflow, suggests that L1521F is in the earliest protostellar stage ($< 10^4$ yr) and contains a substellar mass object. The bolometric (or internal) luminosity of L1521F-IRS suggests that the current mass accretion rate is an order-of-magnitude lower than expected in the standard mass accretion model ($\approx 10^{-6}$ $M_\odot$ yr^{-1}), which may imply that L1521F-IRS is currently in a low activity phase.

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High-Contrast Near-Infrared Imaging Polarimetry of the Protoplanetary Disk around RY Tau

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We present near-infrared coronagraphic imaging polarimetry of RY Tau. The scattered light in the circumstellar environment was imaged at H-band at a high resolution (∼0".05) for the first time, using Subaru-HiCIAO. The observed polarized intensity (PI) distribution shows a butterfly-like distribution of bright emission with an angular scale similar to the disk observed at millimeter wavelengths. This distribution is offset toward the blueshifted jet, indicating the presence of a geometrically thick disk or a remnant envelope, and therefore the earliest stage of the Class II evolutionary phase. We perform comparisons between the observed PI distribution and disk models with: (1) full radiative transfer code, using the spectral energy distribution (SED) to constrain the disk parameters; and (2) monochromatic simulations of scattered light which explore a wide range of parameters space to constrain the disk and dust parameters. We show that these models cannot consistently explain the observed PI distribution, SED, and the viewing angle inferred by millimeter interferometry. We suggest that the scattered light in the near-infrared is associated with an optically thin and geometrically thick layer above the disk surface, with the surface responsible for the infrared SED. Half of the scattered light and thermal radiation in this layer illuminates the disk surface, and this process may significantly affect the thermal structure of the disk.

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Photoevaporation of Circumstellar Disks Revisited: The Dust-Free Case

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Photoevaporation by stellar ionizing radiation is believed to play an important role in the dispersal of disks around young stars. The mass loss model for dust-free disks developed by Hollenbach et al. is currently regarded as a conventional one and has been used in a wide variety of studies. However, the rate in this model was derived by the crude so-called 1+1D approximation of ionizing radiation transfer, which assumes that diffuse radiation propagates in a direction vertical to the disk. In this study, we revisit the photoevaporation of dust-free disks by solving the 2D axisymmetric radiative transfer for steady-state disks. Unlike that solved by the conventional model, we determine that direct stellar radiation is more important than the diffuse field at the disk surface. The radial density distribution at the ionization boundary is represented by the single power-law with an index $-3/2$ in contrast to the conventional double power-law. For this distribution, the photoevaporation rate from the entire disk can be written as a function of the ionizing photon emissivity, $\Phi_{\rm EUV}$, from the central star and the disk outer radius, $r_{\rm d}$, as follows: $\dot{M}_{\rm PE} = 5.4 \times 10^{-5} \times (\Phi_{\rm EUV}/10^{49}\ {\rm sec}^{-1})^{1/2} \times (r_{\rm d}/1000\ {\rm AU})^{1/2}\ M_\odot\ {\rm yr}^{-1}$. This new rate depends on the outer disk radius rather than on the gravitational radius as in the conventional model, caused by the enhanced contribution to the mass loss from the outer disk annuli. In addition, we discuss its applications to present-day as well as primordial star formation.

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The quadruple pre-main sequence system LkCa3: Implications for stellar evolution models

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We report the discovery that the pre-main sequence object LkCa3 in the Taurus-Auriga star-forming region is a hierarchical quadruple system of M stars. It was previously known to be a close ($\sim$0.5$''$) visual pair, with one component being a moderately eccentric 12.94-day single-lined spectroscopic binary. A re-analysis of archival optical spectra complemented with new near-infrared spectroscopy shows both visual components to be double-lined, the second one having a period of 4.06 days and a circular orbit. In addition to the orbital elements, we determine optical and near-infrared flux ratios, effective temperatures, and projected rotational velocities for all four stars. Using existing photometric monitoring observations of the system that had previously revealed the rotational period of the primary in the longer-period binary, we detect also the rotational signal of the primary in the 4.06-day binary, which is synchronized with the orbital motion. With only the assumption of coevality, a comparison of all of these constraints with current stellar evolution models from the Dartmouth series points to an age of 1.4 Myr and a distance of 133 pc, consistent with previous estimates for the region and suggesting the system is on the near side of the Taurus complex. Similar comparisons of the properties of LkCa3 and of the well-known quadruple pre-main sequence system GG Tau with the widely used models from the Lyon series for a mixing length parameter of $\alpha_{\rm ML} = 1.0$ strongly favor the Dartmouth models.

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The dynamical state of the first hydrostatic core candidate Cha-MMS1

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Context. First hydrostatic cores represent a theoretically predicted intermediate evolutionary link between the prestellar and protostellar phases. Studying the observational characteristics of first core candidates is therefore vital for probing and understanding the earliest phases of star formation. *Aims.* We aim to determine the dynamical state of the first hydrostatic core candidate Cha-MMS1.
Methods. We observed Cha-MMS1 in various molecular transitions with the APEX and Mopra telescopes. Continuum data retrieved from the *Spitzer Heritage Archive* were used to estimate the internal luminosity of the source. The molecular emission was modelled with a radiative transfer code to derive constraints on the kinematics of the envelope, which were then compared to predictions of magneto-hydrodynamic simulations.
Results. We derive an internal luminosity of 0.08 $L_\odot$ – 0.18 $L_\odot$ for Cha-MMS1. An average velocity gradient of 3.1 ± 0.1 km s^{-1} pc^{-1} over ~ 0.08 pc is found perpendicular to the filament in which Cha-MMS1 is embedded. The gradient is flatter in the outer parts and, surprisingly, also at the innermost $\sim$ 2000 AU to 4000 AU. The former features are consistent with solid-body rotation beyond 4000 AU and slower, differential rotation beyond 8000 AU, but the origin of the flatter gradient in the innermost parts is unclear. The classical infall signature is detected in HCO^+ 3–2 and CS 2–1. The radiative transfer modelling indicates a uniform infall velocity in the outer parts of the envelope. In the inner parts (at most 9000 AU), an infall velocity field scaling with $r^{-0.5}$ is consistent with the data, but the shape of the profile is less well constrained and the velocity could also decrease toward the centre. The infall velocities are subsonic to transonic, 0.1 km s^{-1} – 0.2 km s^{-1} at $r \geq 3300$ AU, and subsonic to supersonic, 0.04 km s^{-1} – 0.6 km s^{-1} at $r \leq 3300$ AU. Both the internal luminosity of Cha-MMS1 and the infall velocity field in its envelope are consistent with predictions of MHD simulations for the first core phase. There is no evidence of a fast, large-scale outflow stemming from Cha-MMS1, but excess emission from the high-density tracers CS 5–4, CO 6–5, and CO 7–6 suggests the presence of higher velocity material at the inner core.
Conclusions. Its internal luminosity excludes Cha-MMS1 being a prestellar core. The kinematical properties of its envelope are consistent with Cha-MMS1 being a first hydrostatic core candidate or a very young Class 0 protostar.

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A major asymmetric dust trap in a transition disk

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The statistics of discovered exoplanets suggest that planets form efficiently. However, there are fundamental unsolved problems, such as excessive inward drift of particles in protoplanetary disks during planet formation. Recent theories invoke dust traps to overcome this problem. We report the detection of a dust trap in the disk around the star Oph IRS 48 using observations from the Atacama Large Millimeter/submillimeter Array (ALMA). The 0.44-millimeter-

wavelength continuum map shows high-contrast crescent-shaped emission on one side of the star originating from millimeter-sized grains, whereas both the mid-infrared image (micrometer-sized dust) and the gas traced by the carbon monoxide 6-5 rotational line suggest rings centered on the star. The difference in distribution of big grains versus small grains/gas can be modeled with a vortex-shaped dust trap triggered by a companion.

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Fragmenting protostellar discs: properties and observational signatures

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Using numerical hydrodynamic simulations, we study the gravitational fragmentation of an unstable protostellar disc formed during the collapse of a pre-stellar core with a mass of 1.2 $M_\odot$. The forming fragments span a mass range from about a Jupiter mass to very-low-mass protostars and are located at distances from a few tens to a thousand AU, with a dearth of objects at ≤ 100 AU. We explore the possibility of observational detection of the fragments in discs viewed through the outflow cavity at a distance of 250 pc. We demonstrate that one hour of integration time with the Atacama Larger Millimeter/sub-millimeter Array (ALMA) is sufficient to detect the fragments with masses as low as 1.5 $M_{\rm Jup}$ at orbital distances up to 800 AU from the protostar. The ALMA resolution sets the limit on the minimum orbital distance of detectable fragments. For the adopted resolution of our simulated ALMA images of $0.1''$, the fragments can be detected at distances down to 50 AU. At smaller distances, the fragments usually merge with the central density peak. The likelihood for detecting the fragments reduces significantly for a lower resolution of $0.5''$. Some of the most massive fragments, regardless of their orbital distance, can produce characteristic peaks at $\approx 5\mu$m and hence their presence can be indirectly inferred from the observed spectral energy distributions of protostars.

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Optical and Near-Infrared Shocks in the L988 Cloud Complex

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We have searched the Lynds 988 dark cloud complex for optical (Hα and [SII]) and near-IR (H_2 2.12 μm) shocks from protostellar outflows. We find 20 new Herbig-Haro objects and 6 new H_2 shocks (MHO objects), 3 of which are cross detections. Using the morphology in the optical and near-IR, we connect several of these shocks into at least 5 distinct outflow systems and identify their source protostars from catalogs of infrared sources.
Two outflows in the cloud, from IRAS 21014+5001 and IRAS 21007+4951, are in excess of 1 pc in length. The IRAS 21007+4951 outflow has carved a large cavity in the cloud through which background stars can be seen. Also, we have found an optical shock which is the counterflow to the previously discovered "northwest outflow" from LkHα 324SE.

Accepted by The Astronomical Journal

http://arxiv.org/pdf/1307.0881

Clumps and triggered star formation in ionised molecular clouds

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Infrared shells and bubbles are ubiquitous in the Galaxy and can generally be associated with HII regions formed around young, massive stars. In this paper, we use high-resolution 3D SPH simulations to explore the effect of a single O7 star emitting photons at 10^{49} s^{-1} and located at the centre of a molecular cloud with mass 10^4 $M_\odot$ and radius 6.4 pc; the internal structure of the cloud is characterised by its fractal dimension, D (with $2.0 \leq D \leq 2.8$), and the variance of its (log-normal) density distribution, σ_0^2 (with $0.36 \leq \sigma_0^2 \leq 1.42$). Our study focuses on the morphology of the swept-up cold gas and the distribution and statistics of the resulting star formation. If the fractal dimension is low, the border of the HII region is dominated by extended shell-like structures, and these break up into a small number of massive high-density clumps which then spawn star clusters; star formation occurs relatively quickly, and delivers somewhat higher stellar masses. Conversely, if the fractal dimension is high, the border of the HII region is dominated by a large number of pillars and cometary globules, which contain compact dense clumps and tend to spawn single stars or individual multiple systems; star formation occurs later, the stellar masses are somewhat lower, and the stars are more widely distributed.

Accepted by MNRAS

http://arxiv.org/pdf/1306.4317

The Mid-Infrared Extinction Law and its Variation in the Coalsack Nebula

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In recent years the wavelength dependence of interstellar extinction from the ultraviolet (UV), optical, through the near- and mid-infrared (IR) has been studied extensively. Although it is well established that the UV/optical extinction law varies significantly among the different lines of sight, it is not clear how the IR extinction varies among various environments. In this work, using the color-excess method and taking red giants as the extinction tracer, we determine the interstellar extinction Alambda in the four Spitzer/IRAC bands of the Coalsack nebula, a nearby starless dark cloud, based on the data obtained from the 2MASS and Spitzer/GLIMPSE surveys. We select five individual regions across the nebula that span a wide variety of physical conditions, ranging from diffuse, translucent to dense environments, as traced by the visual extinction, the Spitzer/MIPS 24μm emission, and CO emission. We find that Alambda/AKs, the mid-IR extinction relative to AKs, decreases from diffuse to dense environments, which may be explained in terms of ineffective dust growth in dense regions. The mean extinction (relative to AKs) is calculated for the four IRAC bands as well, which exhibits a flat mid-IR extinction law, consistent with previous determinations for other regions. The extinction in the IRAC 4.5micron band is anomalously high, much higher than that of the other three IRAC bands. It cannot be explained in terms of CO and CO_2 ices. The mid-IR extinction in the four IRAC bands have also been derived for four representative regions in the Coalsack Globule 2 which respectively exhibit strong ice absorption, moderate or weak ice absorption, and very weak or no ice absorption. The derived mid-IR extinction curves are all flat, with Alambda/AKs increasing with the decrease of the H_2O ice absorption optical depth.

Accepted by ApJ

http://arxiv.org/pdf/1306.4441

Optical IFU observations of gas pillars surrounding the super star cluster NGC 3603

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We present optical integral field unit (IFU) observations of two gas pillars surrounding the Galactic young massive star cluster NGC 3603. The high S/N and spectral resolution of these data have allowed us to accurately quantify the Hα, [NII] and [SII] emission line shapes, and we find a mixture of broad (FWHM $\sim$70–100 km s^{-1}) and narrow (<50 km s^{-1}) components. The broad components are found close to the edges of both pillars, suggesting that they originate in turbulent mixing layers (TMLs) driven by the effect of the star cluster wind. Both pillars exhibit surprisingly high ionized gas densities of >10000 cm^{-3}. In one pillar we found that these high densities are only found in the narrow component, implying it must originate from deeper within the pillar than the broad component. From this, together with our kinematical data, we conclude that the narrow component traces a photoevaporation flow, and that the TML forms at the interface with the hot wind. On the pillar surfaces we find a consistent offset in radial velocity between the narrow (brighter) components of Hα and [NII] of $\sim$5–8 km s^{-1}, for which we were unable to find a satisfactory explanation. We urge the theoretical community to simulate mechanical and radiative cloud interactions in more detail to address the many unanswered questions raised by this study.

Accepted by MNRAS

http://arxiv.org/pdf/1306.4813

Near-infrared Variability among YSOs in the Star Formation Region Cygnus OB7

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We present an analysis of near-infrared time-series photometry in J, H, and K bands for about 100 epochs of a $1^\circ \times 1^\circ$ region of the Lynds 1003/1004 dark cloud in the Cygnus OB7 region. Augmented by data from the Wide-field Infrared Survey Explorer (WISE), we identify 96 candidate disk bearing young stellar objects (YSOs) in the region. Of these, 30 are clearly Class I or earlier. Using the Wide-Field imaging CAMera (WFCAM) on the United Kingdom InfraRed Telescope (UKIRT), we were able to obtain photometry over three observing seasons, with photometric uncertainty better than 0.05 mag down to $J \approx 17$. We study detailed light curves and color trajectories of $\sim$50 of the YSOs in the monitored field. We investigate the variability and periodicity of the YSOs and find the data are consistent with all YSOs being variable in these wavelengths on time scales of a few years. We divide the variability into four observational classes: 1) stars with periodic variability stable over long timescales, 2) variables which exhibit short-lived cyclic behavior, 3) long duration variables, and 4) stochastic variables. Some YSO variability defies simple classification. We can explain much of the observed variability as being due to dynamic and rotational changes in the disk, including an asymmetric or changing blocking fraction, changes to the inner disk hole size, as well as changes to the accretion rate. Overall, we find that the Class I:Class II ratio of the cluster is consistent with an age of < 1 Myr, with at least one individual, wildly varying, source $\sim 100,000$ yr old. We have also discovered a Class II eclipsing binary system with a period of 17.87 days.

Accepted by ApJ

http://arxiv.org/pdf/1306.2326

High-J CO survey of low-mass protostars observed with *Herschel*-HIFI

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Context: In the deeply embedded stage of star formation, protostars start to heat and disperse their surrounding cloud cores. The evolution of these sources has traditionally been traced through dust continuum spectral energy distributions (SEDs), but the use of CO excitation as an evolutionary probe has not yet been explored due to the lack of high-J CO observations.
Aims: The aim is to constrain the physical characteristics (excitation, kinematics, column density) of the warm gas in low-mass protostellar envelopes using spectrally resolved *Herschel* data of CO and compare those with the colder gas traced by lower excitation lines.
Methods: *Herschel*-HIFI observations of high-J lines of ^{12}CO, ^{13}CO, and C^{18}O (up to $J_{\rm u} = 10$, $E_{\rm u}$ up to 300 K) are presented toward 26 deeply embedded low-mass Class 0 and Class I young stellar objects, obtained as part of the *Water In Star-forming regions with Herschel* (WISH) key program. This is the first large spectrally resolved high-J CO survey conducted for these types of sources. Complementary lower J CO maps were observed using ground-based telescopes, such as the JCMT and APEX and convolved to matching beam sizes.
Results: The ^{12}CO 10–9 line is detected for all objects and can generally be decomposed into a narrow and a broad component owing to the quiescent envelope and entrained outflow material, respectively. The ^{12}CO excitation temperature increases with velocity from ∼60 K up to ∼130 K. The median excitation temperatures for ^{12}CO, ^{13}CO and C^{18}O derived from single-temperature fits to the $J_{\rm u}$=2–10 integrated intensities are ∼70 K, 48 K and 37 K, respectively, with no significant difference between Class 0 and Class I sources and no trend with $M_{\rm env}$ or $L_{\rm bol}$. Thus, in contrast t the continuum SEDs, the spectral line energy distributions (SLEDs) do not show evolution during the embedded stage. In contrast, the integrated line intensities of all CO isotopologs show a clear decrease with evolutionary stage as the envelope is dispersed. Models of the collapse and evolution of protostellar envelopes reproduce the C^{18}O results well, but underproduce the ^{13}CO and ^{12}CO excitation temperatures, due to lack of UV heating and outflow components in those models. The H_2O $1_{10} - 1_{01}$/CO 10–9 intensity ratio does not change significantly with velocity, in contrast to the H_2O/CO 3–2 ratio, indicating that CO 10–9 is the lowest transition for which the line wings probe the same warm shocked gas as H_2O. Modeling of the full suite of C^{18}O lines indicates an abundance profile for Class 0 sources that is consistent with a freeze-out zone below 25 K and evaporation at higher temperatures, but with some fraction of the CO transformed into other species in the cold phase. In contrast, the observations for two Class I sources in Ophiuchus are consistent with a constant high CO abundance profile.
Conclusions: The velocity resolved line profiles trace the evolution from the Class 0 to the Class I phase through decreasing line intensities, less prominent outflow wings, and increasing average CO abundances. However, the CO excitation temperature stays nearly constant. The multiple components found here indicate that the analysis of spectrally unresolved data, such as provided by SPIRE and PACS, must be done with caution.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/1306.3981

Abstracts of recently accepted major reviews

The Formation and Dynamics of Super-Earth Planets

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Super-Earths, objects slightly larger than Earth and slightly smaller than Uranus, have found a special place in exoplanetary science. As a new class of planetary bodies, these objects have challenged models of planet formation at both ends of the spectrum and have triggered a great deal of research on the composition and interior dynamics of rocky planets in connection to their masses and radii. Being relatively easier to detect than an Earth-sized planet at 1 AU around a G star, super-Earths have become the focus of worldwide observational campaigns to search for habitable planets. With a range of masses that allows these objects to retain moderate atmospheres and perhaps even plate tectonics, super-Earths may be habitable if they maintain long-term orbits in the habitable zones of their host stars. Given that in the past two years a few such potentially habitable super-Earths have in fact been discovered, it is necessary to develop a deep understanding of the formation and dynamical evolution of these objects. This article reviews the current state of research on the formation of super-Earths and discusses different models of their formation and dynamical evolution.

Accepted by Annual Review of Earth and Planetary Sciences

http://arxiv.org/pdf/1306.5567.pdf

The stellar and sub-stellar IMF of simple and composite populations

Pavel Kroupa[1], **Carsten Weidner**[2,3], **Jan Pflamm-Altenburg**[1], **Ingo Thies**[1], **Jörg Dabringhausen**[1], **Michael Marks**[1] **& Thomas Maschberger**[4,5]

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The current knowledge on the stellar IMF is documented. It appears to become top-heavy when the star-formation rate density surpasses about $0.1 M_\odot/(\mathrm{yr\ pc}^3)$ on a pc scale and it may become increasingly bottom-heavy with increasing metallicity and in increasingly massive early-type galaxies. It declines quite steeply below about $0.07 M_\odot$ with brown dwarfs (BDs) and very low mass stars having their own IMF. The most massive star of mass m_{max} formed in an embedded cluster with stellar mass M_{ecl} correlates strongly with Mecl being a result of gravitation-driven but resource-limited growth and fragmentation induced starvation. There is no convincing evidence whatsoever that massive stars do form in isolation. Various methods of discretising a stellar population are introduced: optimal sampling leads to a mass distribution that perfectly represents the exact form of the desired IMF and the m_{max}-to-M_{ecl} relation, while random sampling results in statistical variations of the shape of the IMF. The observed m_{max}-to-M_{ecl} correlation and the small spread of IMF power-law indices together suggest that optimally sampling the IMF may be the more realistic description of star formation than random sampling from a universal IMF with a constant upper mass limit. Composite populations on galaxy scales, which are formed from many pc scale star formation events, need to be described by the integrated galactic IMF. This IGIMF varies systematically from top-light to top-heavy in dependence of galaxy type and star formation rate, with dramatic implications for theories of galaxy formation and evolution.

Accepted by Stellar Systems and Galactic Structure, vol.5, Springer

http://arxiv.org/pdf/1112.3340v3

Dissertation Abstracts

The Structure and Evolution of Massive Star and Cluster Forming Regions

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Ph.D dissertation directed by: John Bally

Ph.D degree awarded: August 2013

The formation of massive stars and stellar clusters is important in understanding the light we receive from other galaxies, the life cycle of matter in the Galaxy, and the global process of star formation. However, this problem has remained elusive as the relative rarity, large distances, confusion, and obscured nature of massive star forming regions has made a global and high-resolution understanding of their formation intractable for decades. The advent of large Galactic Plane Surveys and high-resolution observing facilities have allowed us to make large strides in this field by constraining the physical properties at the onset of massive star formation in clustered environments, identifying the stages of massive star formation, and estimating the lifetimes of these phases.

We present a detailed analysis of two young massive star forming regions in different evolutionary stages embedded within a single Infrared Dark Cloud using NH_3 on the Karl G. Jansky Very Large Array. In this analysis, we characterize the physical structure (column density, temperature, and virial parameter) just prior to the onset of massive star formation and infer evolution in this structure by measuring it at different evolutionary stages. We expand this analysis to a global scale using Herschel and Spitzer surveys of the Galactic Plane from mid-to far-IR, devising a method to identify precursors to stellar clusters throughout the Galaxy for the first time. By separating the diffuse Galactic cirrus emission from the dense molecular clumps, we derive the dust temperatures and column densities characteristic of cluster-forming clumps. We compare these physical properties with star formation tracers in a systematic way to distinguish and characterize their evolutionary phases. We compare the physical properties derived from gas with those derived using dust. We estimate lifetimes for these evolutionary phases and speculate on the large-scale dynamics in the formation of stellar clusters.

We constrain the conditions at the onset of massive star formation, measure how these conditions change with evolutionary phase, and estimate the duration of each phase. This thesis places global and high-resolution constraints on the physical properties, evolution, and lifetimes of massive star and cluster forming regions.

Observations of Warm Water in Young Solar-System Analogs Origin, abundances and deuterium fractionation

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Ph.D dissertation directed by: Jes Jørgensen

Ph.D degree awarded: June 2013

In star formation, water is an essential molecule. It affects the oxygen based chemistry, the physical conditions and energy balance in the protostellar envelope, and it is associated with the emergence of life as we know it. In the thesis, high-resolution ground-based observations of the $H_2^{18}O$, and HDO isotopologues are presented toward four sources in a small survey conducted with several interferometric telescopes. $H_2^{18}O$ is compared to the other molecules detected, i.e. CH_3OCH_3 (dimethyl ether), C_2H_5CN (ethyl cyanide) and SO_2 (sulfur dioxide). The amount of warm water is deduced and its origin is observationally constrained. With both isotopologues observed, the HDO/H_2O ratio is deduced. This ratio is then compared to other sources, e.g., comets and the Earth s ocean, to gain understanding of the origin of the water in our own solar system. The emission line fluxes are modeled with radiative transfer tools and compared to other results of water abundances in the same source. The observed water emission, both $H_2^{18}O$ and HDO is compact for all observed sources and traces the emission on $R \approx 150$ AU scales or less. In one source the water is seen in absorption, with a inverse P-Cygni spectral profile - an indication of infalling motions. The similar line characteristics of water and the other detected molecules in the frequency band, together with the absorption toward one source, shows that these water lines are not masing. Under the assumption of local thermal equilibrium (LTE) and a excitation temperature derived from two observed HDO lines toward one source, abundances are derived, and a corresponding HDO/H_2O ratio. This method gives a partially model independent estimate of the amount of water deuterium fractionation in protostars. From non-LTE radiative transfer modeling of spherically symmetric models we show that while the HDO line is becoming marginally optically thick, the $H_2^{18}O$ line is optically thin. The modeling results are useful to assess the validity of LTE and optical thickness. However, for deriving fractional abundances, the LTE approximation and modeling gives results that agree within the uncertainties. The other molecules detected in the observations of the $H_2^{18}O$ show similar line widths to water. The abundances of dimethyl ether (CH_3OCH_3) and sulfur dioxide (SO_2) in relation to water (H_2O) are roughly equal between the individual sources. The ethyl cyanide (C_2H_5CN) on the other hand, is not. This indicates that similar chemical processes are at work for dimethyl ether, sulfur dioxide and water.

http://vilhelm.nu

New Jobs

PhD studentship in Groningen:
Massive star formation from Herschel to ALMA

The ALMA telescope is a great opportunity to study long-standing questions in high-mass star formation in novel ways. In particular, its high sensitivity and angular resolution allow us to trace the flow of matter from cores via disks onto protostars and into jets and outflows with unprecedented precision. In this project, a PhD student will perform ALMA observations of high-mass star-forming regions. Specific science goals are the accretion mechanisms (monolithic vs competitive), the kinematics of circumstellar disks (solid-body vs Keplerian; as a function of mass and age) and the onset of bipolar outflows (stellar wind vs disk wind). A major new step will be the use of continuum observations to probe low-mass companions to young high-mass stars, which addresses the origin of stellar multiplicity, but also takes existing work on the protostellar core mass function to the stellar scale, thus directly addressing the origin of the IMF. Multi-wavelength observations will be essential to disentangle the contributions of free-free and dust emission to the observed continuum. A special role in this project is played by observations of H_2O and $H_2^{18}O$ lines in ALMA Band 5 (built by NOVA Groningen). Multi-line observations with Herschel-HIFI have shown large H_2O abundance variations within star-forming regions, suggesting that H_2O is highly localized where gas is accelerated. The proposed ALMA observations are essential to understand the origin of the H_2O seen with Herschel, and its destiny. Other lines of common tracers of kinematics and physical conditions such as CO, CS and CH_3CN will be observed simultaneously with the multi-band continuum. Sources will be drawn from the Herschel key project on water, and other surveys.

Supervisor: Floris van der Tak http://www.sron.rug.nl/~vdtak/

Applications: http://jobregister.aas.org/job_view?JobID=45166

More information: http://www.rug.nl/research/kapteyn/vacatures/vacancies

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The Orion Nebula Cluster as a Paradigm for Star Formation

a Space Telescope Science Institute mini-workshop

Baltimore, MD, October 14-16, 2013

Objective:

As the nearest young cluster dominated by massive OB stars, the Orion Nebula Cluster plays a paradigmatic role in our understanding of star and planet formation. The wealth of ground-based and HST data collected in recent years is allowing to study with unprecedented detail the products of the star formation process: stellar mass distribution, age spread, mutiplicity, activity, cluster's spatial and kinematic structure, etc. These data provide a fundamental reference for comparison with other regions, as well as a critical benchmark for theoretical models and numerical simulations.

This workshop is an opportunity to discuss what we have learned from Orion so far, focusing on open problems and new directions of observational and theoretical research. Emphasis will be given to the role played by the Orion Nebula Cluster as a paradigm for the early solar environment, as well as for present-day star formation in different environments, including the Galactic center and the Magellanic Clouds.

Organizing Committee:

Massimo Robberto, STScI (Chair)
Nicola Da Rio, U. Florida
Selma de Mink, Carnegie/Caltech & Princeton
Mario Gennaro, STScI
Lee Hartmann, University of Michigan
Lynne A. Hillenbrand, Caltech
Dave Soderblom, STScI
Jonathan Tan, U. Florida
Sherita Hanna (administrative support, hanna@stsci.edu)

https://www.facebook.com/TheOrionNebulaClusterAsAParadigmOfStarFormation

A web site will be announced soon

Characterizing Planetary Systems Across the HR Diagram

Institute of Astronomy, University of Cambridge, Cambridge, United Kingdom

28 July - 1 August 2014, acrosshr@ast.cam.ac.uk

http://www.ast.cam.ac.uk/meetings/2013/AcrossHR

The University of Cambridge Institute of Astronomy will host a 5 day scientific meeting to further our understanding of the formation and evolution of planetary systems. The meeting will focus on the full lifetime of planetary systems, from pre- to post-main sequence host star stages, and the connections that can be made by viewing these evolutionary stages as parts of a whole. In this way, the program aims to provide an integrative approach rather than focusing on each stellar stage separately.

We will bring together participants from the growing diversity of planetary science disciplines: star-planet formation, solar system studies, exoplanets, debris disks, host star abundances and atmospheric pollution, stellar evolution, and planetary dynamics. The conference can accommodate up to 150 people.

The overall goal of the meeting is to generate discussion and increase scientific interactions among the diverse communities interested in the formation, architecture, and evolution of planetary systems. Two themes that represent the spirit of the meeting are:

1) The physical and chemical connections between evolved planetary systems, their main-sequence counterparts, and those forming in proto-planetary disks.

2) The scientific potential for extracting planetary system frequency, structure, chemistry, and dynamics at different evolutionary phases and stellar populations.

Session Topics will include:

- Proto-planetary disk and planetary atmosphere chemistry
- Planetesimal and solid planet compositions
- Planet and debris populations
- Host star elemental abundances and pollution
- Planetary system and host star evolution

Planet Formation and Evolution 2014

10 - 12 September 2014 Kiel, Germany

http://www1.astrophysik.uni-kiel.de/~kiel2014/main/

The aim of this workshop is to intensify the interaction between the research communities in the fields of planet formation, exo-planets, and the solar system. The workshop will be held at Christian-Albrechts-Universität zu Kiel.

SOC:

Sebastian Wolf (Chair, Kiel)
Robert Wimmer-Schweingruber (Kiel)
Barbara Ercolano (Mnchen)
Thomas Preibisch (Mnchen)
Stephan Dreizler (Gttingen)
Willy Kley (Tbingen)
Jrgen Blum (Braunschweig)
Mario Trieloff (Heidelberg)
Gerhard Wurm (Duisburg)
Artie Hatzes (Tautenburg)
Heike Rauer (Berlin)

IAUS 302 - Magnetic Fields Throughout Stellar Evolution Full program and registration deadline

The program of IAUS 302 is now available online at the following address:
http://iaus302.sciencesconf.org/program

The full list of abstracts (including posters) can be found here:
http://iaus302.sciencesconf.org/browse/session

The deadline for registration is on July 21! To join us in Biarritz at the end of August, we invite you to proceed to the registration page:
http://iaus302.sciencesconf.org/registration/index

Meetings of Possible Interest

Protostars and Planets VI
15 - 20 July 2013 Heidelberg, Germany
http://www.ppvi.org

Dust Growth in Star & Planet Formation 2013
22 - 25 July 2013 MPIA, Heidelberg, Germany
http://www.mpia.de/DG13/

2013 Sagan Summer Workshop: Imaging Planets and Disks
29 July - 2 August 2013 Pasadena, CA, USA
http://nexsci.caltech.edu/workshop/2013/

IAUS 302 - Magnetic Fields Throughout Stellar Evolution
26 - 30 August 2013 Biarritz, France
http://iaus302.sciencesconf.org

Meteoroids 2013. An International Conference on Minor Bodies in the Solar System
26 - 30 August 2013 Dep. of Physics, A.M. University, Poznan, Poland
http://www.astro.amu.edu.pl/Meteoroids2013/index.php

Exoplanets and Brown Dwarfs
2 - 5 September 2013 de Havilland, University of Hertfordshire, Hatfield, Nr. London, UK
no web site yet

Evolution of Star Clusters: From Star Formation to Cosmic Ages
24 - 27 September 2013
Splinter Meeting E at the Annual Meeting of the Astronomische Gesellschaft, Tübingen, Germany
http://www-astro.physik.tu-berlin.de/~harfst/AG2013_SplinterE/

Dust Radiative Transfer - Codes and Benchmarks 9 - 11 October 2013
http://ipag.osug.fr/RT13/index.php

The Orion Nebula Cluster as a Paradigm for Star Formation
14 - 16 October 2013 STScI, Baltimore, USA
no web site yet

400 Years of Stellar Rotation
17 - 22 November 2013, Natal, Brazil
http://www.dfte.ufrn.br/400rotation/

The Life Cycle of Dust in the Universe: Observations, Theory, and Laboratory Experiments
18 - 22 November 2013 Taipei, Taiwan
http://events.asiaa.sinica.edu.tw/meeting/20131118/

An Olympian Symposium for Star Formation
26 - 30 May 2014 Paralia Katerinis, Mount Olympus, Greece
http://zuserver2.star.ucl.ac.uk/$\sim$tb/

EPoS2014 The Early Phase of Star Formation
1 - 6 June 2014 Ringberg Castle, Tegernsee, Germany
http://www.mpia-hd.mpg.de/homes/stein/EPoS/epos.php

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

Living Together: Planets, Stellar Binaries and Stars with Planets
8 - 12 September 2014 Litomysl Castle, Litomysl, Czech Republic
http://astro.physics.muni.cz/kopal2014/

Planet Formation and Evolution 2014
10 - 12 September 2014 Kiel, Germany
http://www1.astrophysik.uni-kiel.de/$\sim$2014/main/

Towards Other Earths II. The Star-Planet Connection
15 - 19 September 2014 Portugal
http://www.astro.up.pt/toe2014

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