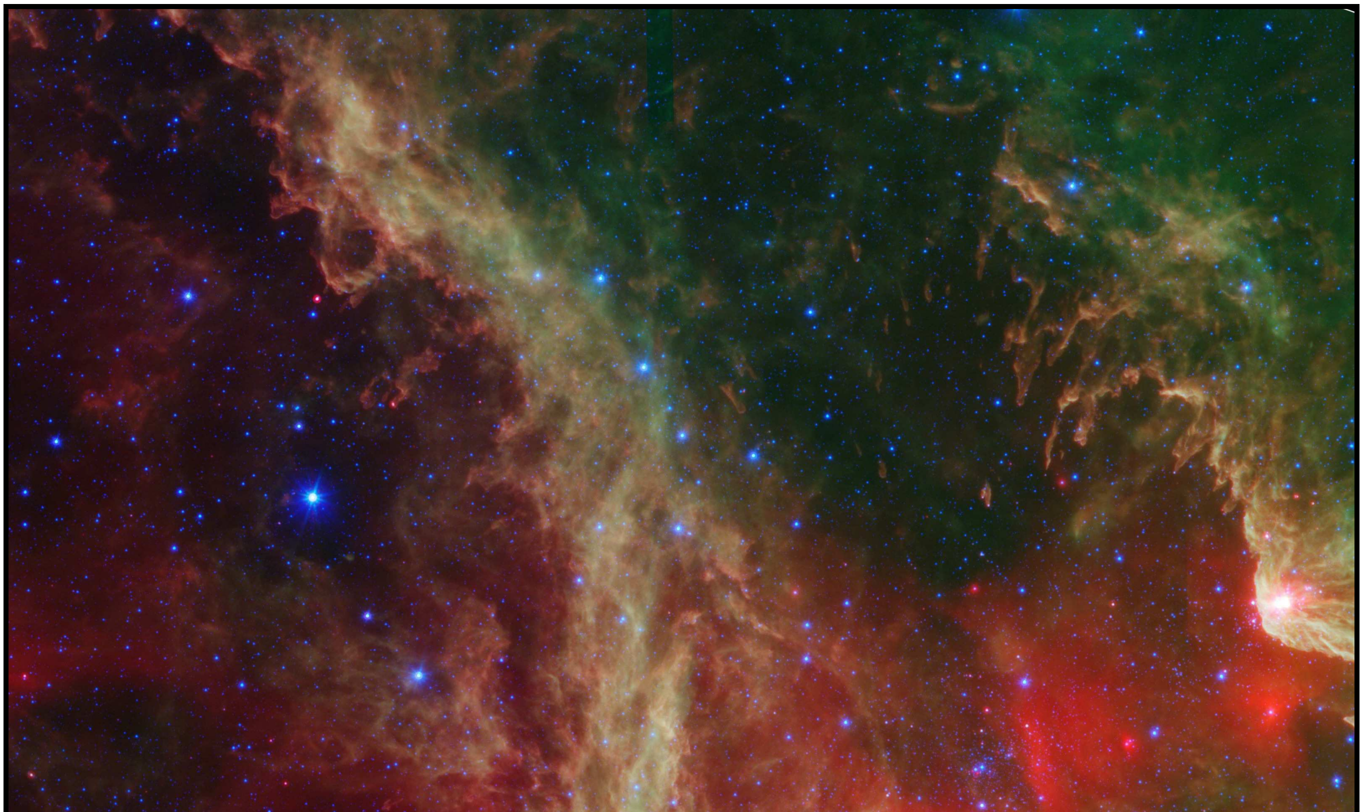
THE STAR FORMATION NEWSLETTER

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

No. 279 — 16 March 2016 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)



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

W5 is a major star forming region in the Perseus arm of our Galaxy at a distance of 1.95 kpc. W5 harbors the young cluster IC 1848 which contains a small group of O-stars that excite a large bubble-shaped HII region. The cover picture is a three-color composite showing infrared observations from two Spitzer instruments. Blue represents 3.6-micron light and green shows light of 8 microns, both captured by Spitzer's infrared array camera. Red is 24-micron light detected by Spitzer's multiband imaging photometer.

Image courtesy Jet Propulsion Laboratory and Caltech.

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

Yasuo Fukui

in conversation with Bo Reipurth

Q: *How did you enter into the field of molecular clouds and star formation?*

A: I originally thought of majoring in high energy astrophysics when I was an undergraduate student. I changed my mind when I attended lectures on a new field, interstellar molecules, given by Takeshi Oka. I found that interstellar molecular clouds were new and so fascinating. I was also attracted by the problem of star formation. The MNRAS paper by Richard Larson in 1969 was one of my most favorite papers. In the graduate program, I joined the radio astronomy group in Tokyo Observatory (now NAOJ) and used the 6 m telescope to map molecular clouds at 3 mm wavelength. The Sgr A molecular cloud was my thesis topic.

Q: *You have made major surveys with the Nagoya 4 m millimeter wave telescope. What is the history of this telescope?*

A: I moved to Nagoya in 1980 and built the 4m mm telescope in 1982 – 1984. I lead the Nagoya team in designing the telescope with a skillful craftsman with a wealth of experience. He manufactured the telescope in his small machine shop. The budget was limited and 4 m was the maximum dish diameter we could afford in a small university laboratory. Later, I realized that the choice of the dish size was right, particularly for observing star forming regions at pc scale resolution over a large field. 4 m is not too small but also not too large. I also lead the development of low noise receivers since the receiver sensitivity is the key for large scale mapping. In 1990 the Nagoya team developed an SIS mixer receiver of the best noise temperature at the CO $J = 1 - 0$ wavelength. Later, the noise temperature was adopted as the design goal of the ALMA band 3 receiver.

Q: *In 1986 you made a large unbiased survey of molecular clouds searching for outflows, and many of those you found are now classic outflows. How have your conclusions held up with time?*

A: The Nagoya team discovered more than 50 outflows in the survey as reviewed in PPIII etc. Around 1990 we reached two conclusions. First, the discoveries showed that molecular outflows are driven not only by high luminosity stars like the Orion BN object but also by sun-like low-luminosity stars. This supports the idea that the solar-type stars commonly experience the outflow phase. Second, outflows were shown to be associated with driving sources having very red spectral energy distributions, implying that they are in the mass - accretion phase, most probably protostars. These conclusions are consistent with the outcomes of subsequent studies and are now common knowledge. In the astrophysics of outflows, it still remains to be tested observationally if the details of launching an outflow matches theories, including the confirmation of its spinning motion along its axis.

Q: *More recently you have explored the southern sky with the NANTEN and NANTEN2 telescopes. Please describe these facilities.*

A: I had a plan to build a southern mm observatory in 1987. Discussions with Mitsuaki Fujimoto inspired me toward the Magellanic Clouds and other southern objects. I learned that the Magellanic Clouds are an interesting system where young populous clusters similar to the globulars are forming. One of my motivations in the southern project was to study the formation of the populous clusters, and I also thought the southern survey could offer valuable insights. However, I found it difficult to build an observatory in Chile at that time because there was no legal basis for installing a Japanese telescope in foreign countries. The first step I took was to build a new 4m telescope in Nagoya while I sustained my efforts for its transfer to Chile. After a while, the government suggested that I make a campaign for fund-raising to secure the operational costs of the observatory. I thought this over and in 1994 started to seek contributions from a few hundred private companies and the public. I gave a number of public lectures on the southern project and finally amassed the necessary funds. The government then supported to move the telescope to Chile. I installed the new 4m telescope at Las Campanas Observatory in 1996 and named it NANTEN ("the southern sky" in Japanese) through a call to the public for suggestions. The Nagoya team surveyed the CO $J = 1 - 0$ emission in the southern Milky Way and the Magellanic Clouds. In 8 years we almost finished the survey from the low altitude (2000m) site and decided to move the telescope to a higher place good for sub-mm operation. In 2004 we upgraded the telescope by changing the main dish with one having three times higher accuracy and we enclosed the telescope by an astrodome to achieve higher pointing and surface accuracy. This new sub-mm facility was named NANTEN2 and was installed in Atacama at an altitude of 4865m.

Q: *In your 2010 Annual Reviews article with Akiko Kawamura you summarize your work with NANTEN on the Magellanic Clouds. What are your main conclusions?*

A: With NANTEN we covered the whole LMC and SMC in CO emission and mapped 300 GMCs over the period 1997–2003. This is the first sample of resolved GMCs covering a single galaxy and allowed us to make reasonable statistics of GMCs. The Milky Way is too much contaminated toward the disk and one could see only a small number of resolved GMCs. The nearly 300 GMCs in the LMC are classified into three types, "starless GMC", "GMC with only a few O stars", and "GMC with clusters and HII regions" and we interpret that these types indicate evolutionary stages from low- to high-level of star formation in a typical GMC lifetime of 20–30 Myr. Thanks to the full coverage over the galaxy, we were able to correlate GMCs and young clusters with known age and estimate evolutionary timescales of GMCs for the steady state. Later in 2012 the IRAM 30 m telescope was used to make a study of GMCs in M 33 at a similar spatial resolution and the evolutionary trend was confirmed. The GMC evolution we presented is now a canonical picture.

Q: *In a study of the super star cluster NGC 3603 you have found evidence that it formed as a result of a cloud-cloud collision. Is this a rare or a common process?*

A: It is commonly thought that such collisions are very rare in triggering O star formation. During the last 5 years I have been studying O star forming regions in detail to see if there are any signatures for similar collisions. As a result I am finding evidence for cloud-cloud collision in more than ten O star/super star clusters. They include well-known HII regions like RCW 38 as well as N 159 in the LMC, and might suggest that cloud-cloud collision is more frequent than normally thought. Our experience in this study shows that observable signatures for collision are often subtle due to the projection which makes the velocity difference between the two clouds apparently small. The rapid cloud dispersal by ionization is another effect which makes it difficult to recognize the two clouds. In addition, the colliding clouds show a variety of morphology as a natural result of diversity in the cloud shape and often do not allow applying a simple picture of two clear overlapping clouds. At the moment it is premature to say that collisions are common in the formation of O stars. In a couple of years, I hope to have a clear answer to your question whether collisions are rare or common by completing a detailed study of several tens of molecular clouds associated with young HII regions.

Q: *Most recently, using ALMA, you have studied star formation in N 159 in the LMC, and discovered the first extragalactic molecular outflows. You also found evidence for triggered star formation as a result of filament collisions. Please summarize your results.*

A: N 159 is the most active on-going star-forming region in the LMC among the NANTEN GMCs. So, we chose it as the first target for ALMA in the LMC. In the ALMA images we found that the N 159 GMC consists of a number of filamentary clouds like in the Milky Way and that a couple of young O stars are located toward crossing regions of two filaments. Two of these young stars are found to drive outflows of a small age like 10^4 yrs, and one of them is a $40\,M_\odot$ young star N 159W-S. We found bipolar outflow toward two overlapping filaments and the clump shows large velocity dispersion characteristic of a collisionally shocked layer. The projected velocity separation of the two filaments is only $2\,\mathrm{km\,s^{-1}}$ but we infer the actual difference is about $10\,\mathrm{km}\,s^{-1}$ since the theoretical work on colliding clouds indicate the isotropic turbulence is enhanced in the collision-shocked layer (Inoue and Fukui 2013).

Q: *What are your ongoing or future projects?*

A: First, a project directly related to cloud-cloud collision is in progress. In order to test signatures of collision we are mapping molecular clouds toward young HII regions at different angular resolutions of $1''$–$160''$ with several different telescopes in CO and other molecules. Second, we are studying the molecular clouds toward SNRs. Our primary goal is to establish that cosmic ray protons are accelerated in SNRs. This goal will be attained by finding a good spatial correlation between gamma rays and interstellar protons because the gamma rays are emitted via proton-proton collisions at high energy. The third project is to extend the CO survey to more of the sky. Currently, the Nagoya team is working to develop a new receiver with 4 beams and dual polarization at the CO $J = 1 - 0$ frequency. Our present coverage of CO is still limited and we aim to map 70 % of the whole sky with high resolution. This may take several years. The data will be used to correlate with dust emission etc. in order to better understand the interstellar medium. By comparing the Planck dust emission with the 21 cm HI emission we came to the conclusion that HI emission is usually optically thick if we assume a constant dust to gas ratio and the local HI density may be doubled by the HI opacity correction. It is still an unresolved issue how HI is converted into H_2 via dust-surface reactions and our understanding on the transition is still vague. I am planning to combine the data of gamma rays, HI, CO, and dust emission/extinction to construct an improved picture of the interstellar medium.

My Favorite Object

LkCa 15: A Natural Laboratory for Planet Formation Studies

Steph Sallum

T Tauri Stars and Transition Disks

In the late 1940's, Herbig and Haro independently discovered peculiar emission-line variables with compact nebulae. Initially these objects were interpreted as field stars accreting material from clouds through which they were passing (e.g. Herbig 1948). Later the hypothesis emerged that these T Tauri stars are young, intermediate mass stars that are still contracting and have not yet reached the main sequence (e.g. Ambartsumian 1947, 1949, 1952, 1954; Parenago 1950). Indeed, comparison of their positions on the HR diagram with theoretical evolutionary tracks yields an upper age limit of 10 Myr (D'Antona & Mazzitelli 1994; Swenson et al. 1994). Spectral and photometric surveys showed that some T Tauri stars have Ca II lines in emission, including LkCa 15 (e.g., Herbig et al. 1986).

A survey of T Tauri stars led to the discovery of transition disks, protoplanetary disks with inner clearings. Strom et al. (1989) compiled spectral energy distributions (SEDs) of 83 T Tauri stars, all of which showed infrared excesses indicative of disks. They noted a subset of stars that exhibited near-infrared deficits accompanied by mid- to far-infrared excesses. Studies have interpreted these features as a lack of warm dust at small stellocentric radii, and suggested that these objects may be in transition from filled protoplanetary disks with excess throughout the infrared to debris disks with only weak far-infrared excess. (e.g. Lin & Papaloizou 1986, 1993; Bryden et al. 1999; Calvet et al. 2002). Later modeling of *Spitzer* spectra (e.g. Calvet et al. 2005; Brown et al. 2007; Espaillat et al. 2007 a,b; Merin et al. 2010) also interpreted infrared deficits as inner disk clearings. Followup sub-millimeter imaging has confirmed these inner clearings in a number of transition disks (e.g. Brown et al. 2009; Hughes et al. 2009, Andrews et al. 2011). Transition disks present an opportunity to study planet formation in action, as a possible cause for their inner clearings is the presence of planetary mass companions (e.g. Najita et al. 2007; Lin & Papaloizou 1986; Bryden et al. 1999; Crida et al. 2006).

LkCa 15: A Gapped Disk with a Companion Candidate

LkCa 15 is a $2\pm_1^2$ Myr old solar analog (Kraus & Hillenbrand 2009). It hosts a "pre-transitional" disk, with an SED indicative of a large gap between inner and outer disks (e.g. Strom et al. 1989, Bergin et al 2004, Espaillat et al. 2007a). *Spitzer* SED fitting indicates an optically thick outer disk with an inner edge at 46 AU and an optically thick inner disk extending to < 0.15 AU (Espaillat et al. 2007a, Espaillat et al. 2008). Sub-mm and mm continuum observations confirm this disk gap, with reported inner edges of ~ 50 AU (see Figure 1; e.g. Pietu et al. 2006, Brown et al. 2009, Andrews et al. 2011). Scattered light observations reveal a disk gap (e.g. Thalmann et al. 2010, 2014), as well as an offset between the disk center and the star. More recent optical polarimetry probed the inner disk, tracing its extent out to a radius of 30 AU (Thalmann et al. 2015).

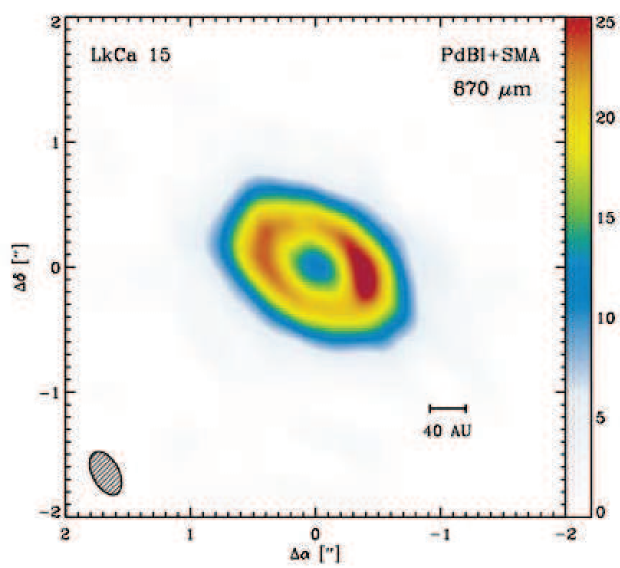

Figure 1: From Andrews et al. (2011). 870 μm continuum image of the LkCa 15 disk synthesized from Plateau de Bure interferometer and Submillimeter Array observations. These observations confirm the disk clearing inferred from SED fitting.

In 2009-2010 Keck infrared observations, Kraus & Ireland (2012) detected multiple infrared point sources in the LkCa 15 disc gap. Followup Keck data placed an upper H-band limit with a contrast of 7.2 magnitudes on all emission in the disk clearing, while direct imaging at M-band revealed a strong (contrast of 3.5 magnitudes) detection in the disk clearing (Ireland & Kraus 2014). Changes in the companion position angles appeared to indicate co-orbital motion at ~ 20 AU (Kraus & Ireland 2012; Ireland & Kraus 2014), leading to the hypothesis that the central, bluest infrared source was a single protoplanet accreting material from its co-orbital surroundings (two redder flanking infrared sources). Later studies attempting to detect accretion signatures from this companion candidate in mm wavelengths and emission lines were unsuccessful (Isella et al. 2014, Whelan et al. 2015).

Accreting Protoplanets in the LkCa 15 Transition Disk

Sallum et al. (2015a) observed LkCa 15 with the Large Binocular Telescope (LBT) at Ks ($\lambda_c = 2.16\ \mu m$) and L′ ($\lambda_c = 3.7\ \mu m$) using the high contrast imaging technique of non-redundant masking (NRM; Tuthill et al. 2000). NRM transforms a filled aperture into an interferometric array; the images show the interference fringes formed by the mask. The observables (complex visibilities) are calculated by taking the Fourier transform of the images, and model fitting and image reconstruction may be used to investigate the source brightness distribution. While reducing throughput to $\sim 10\%$, NRM enables much better point spread function (PSF) characterization than a conventional telescope, allowing observers to probe angular scales even within the diffraction limit.

The LBT observations reveal multiple companions in the LkCa 15 disk gap (see Figure 2), with three point sources at L′ (LkCa 15 b, c, and d). LkCa 15 b and c coincide with LBT Ks detections. The following companion parameters were derived using a star plus 3-companion model fit to the data. The L′ and Ks contrasts for b are 5.0 ± 0.5 and 6.0 ± 0.5 magnitudes, respectively. LkCa 15 c has L′ and Ks contrasts of 5.0 ± 0.5 and 5.5 ± 0.5 magnitudes, and LkCa 15 d's L′ contrast is $5.9\pm^{2.1}_{5.4}$ magnitudes. Since d is fainter than b and c and only detected in one wavelength we focus on LkCa 15 b and c.

We also observed LkCa 15 using the Magellan Adaptive Optics System (MagAO) at Hα ($\lambda_c = 655.8$ nm) in simultaneous differential imaging mode (SDI; Marois et al. 2003). SDI involves imaging in two narrowband filters simultaneously; in this case Hα and the nearby continuum ($\lambda_c = 642$ nm). The continuum provides a probe of the PSF; subtraction of the continuum observations from the Hα observations isolates sources emitting at Hα. LkCa 15 b is detected in Hα with a contrast of 5.2 ± 0.3 magnitudes. Hα traces accretion directly, as hydrogen gas falling into the potential well of a forming planet will become shock heated to $\sim 10,000$ K.

LkCa 15 b and c have joint L′+Ks stellocentric separations of $95\pm^{50}_{15}$ and $80\pm^{15}_{10}$ milliarcseconds, respectively. The large separation errors come from a known degeneracy between companion separation and contrast in NRM observations (Sallum et al. 2015b). Due to this degeneracy, position angle is a much more robust measurement than companion separation or contrast.

In order to fit orbits for LkCa 15 b, c and d to archival Keck data as well as the new observations, companion parameter errors needed to be estimated consistently. Kraus & Ireland (2012) published companion errors generated by MPFIT, a nonlinear fitter that uses the Levenberg-Marquardt algorithm (Marquardt 2009). However, MPFIT is known to become trapped in local minima and to underestimate errors. For this reason, Sallum et al. (2015a) estimated companion errors using a grid of models computed with the University of Arizona's El Gato supercomputer (see Figure 3). We used a χ^2 interval to select companion parameters around the best fit that are allowed at 1σ confidence. While more computationally expensive, this method provided more robust companion parameter errors than MPFIT. We used this grid, along with the raw scatter in the Keck observations, to estimate the grid-based errors for the archival Keck data.

Figure 3 shows orbital fits to the LBT and MagAO source positions as well as the reanalyzed Keck observations for LkCa 15 b and c. Model orbits were constrained to be circular and have the same orientation as the outer disk (inclination $i = 50°$; position angle $\theta = 150°$; Thalmann et al. 2014). Circular orbits in the outer disk plane with semimajor axes of 14.7 ± 2.1 AU and 18.6 ± 2.6 AU provide the best fit to the LkCa 15 b and c positions, respectively. LkCa 15 d's orbit is more poorly constrained with a best fit of $18.0\pm^{6.7}_{5.4}$ AU.

Stable orbits exist within the 1σ allowed semimajor axes for reasonable planet masses. In the absence of a resonance, LkCa 15 b and c must be less than 5 Jupiter masses (M_J) for stability (Gladman 1993). With a 2:1 resonance, their masses can increase to 10 M_J. Including LkCa 15 d in the system decreases the allowed masses, with three 0.5 M_J planets stable for 10 Myr. Higher masses for b and c are allowed in the case of a less massive d.

The observed infrared fluxes agree with theoretical predictions of circumplanetary disk models. From the observed infrared contrasts, LkCa 15 b has fluxes of 2.5 ± 1.2 mJy at L′ and 1.4 ± 0.7 mJy at Ks; LkCa 15 c has fluxes of 2.5 ± 1.2 mJy at L′ and 2.3 ± 1.1 mJy at Ks. Figure 3 shows these fluxes as well as a previously-published H-band upper limit

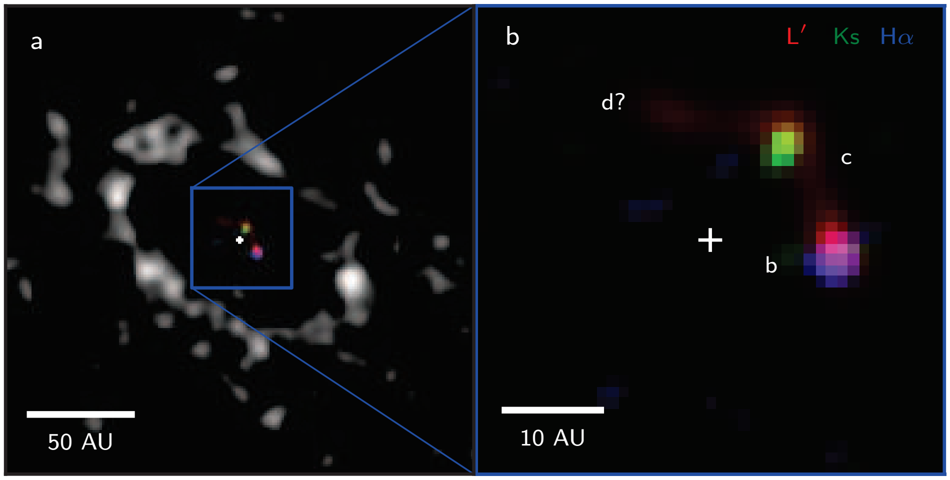

Figure 2: From Sallum et al. (2015a) a) Reconstructed LBT L′ and Ks images (red and green, respectively) and MagAO Hα image (blue) shown at the same plate scale as VLA mm observations (Isella et al. 2014). b) Zoomed in.

(Ireland & Kraus 2014) on all sources within the disk gap. We compare the infrared fluxes to hot-start (high initial entropy; Spiegel & Burrows 2012) substellar companion models after accretion has ceased. Here, all emission originates from the cooling protoplanetary surface. We also compare the fluxes to circumplanetary disk models (Eisner 2015), in which emission originates from a disk around the accreting protoplanet. The fluxes agree with accretion disk models having planet masses times accretion rates of $M_p\dot{M} \simeq 10^{-5} M_J^2$ yr^{-1} for LkCa 15 b and c, and $M_p\dot{M} \simeq 5 \times 10^{-6} M_J^2$ yr^{-1} for LkCa 15 d, assuming inner disk radii of $R_{in} = 2$ R_J. Given the large uncertainties on both the infrared fluxes and colors, a $M_p\dot{M} \simeq 3 \times 10^{-6} M_J^2$ with $R_{in} = 1$ R_J can also reproduce the observations. This $M_p\dot{M}$ value for b agrees with that derived from the Hα luminosity ($3{\times}10^{-6} M_J^2$ yr^{-1}).

In order to reproduce the L′ and Ks fluxes, the hot start models must be 10 M_J, which would lead to unstable orbits for b and c without a 2:1 resonance. Furthermore, the hot-start model can only satisfy the H-band upper limit with significantly higher extinction toward the companions than inferred toward the star. Additionally, Ireland & Kraus 2014 reported a strong M band detection (contrast of 3.5 magnitudes); the hot start model cannot reproduce this increase in observed flux with increasing wavelength. Lastly, a cooling photosphere cannot produce Hα emission, ruling out the hot-start model as the source of b's flux.

The explanation for the initial companion candidate detection (Kraus & Ireland 2012) was the presence of a single protoplanet (corresponding to LkCa 15 c in Sallum et al. 2015a), flanked by co-orbital material from which it was accreting (LkCa 15 b and d in Sallum et al. 2015a). However, the size of the emission ($\sim$ 10 AU) is much larger than the Hill radius for even a 10 M_J planet at 10 AU ($\sim$ 1.8 AU). The three sources cannot be gravitationally bound and an alternative scenario is required to explain the data.

One alternative explanation is the presence of optically thin, clumpy dust orbiting in the disk clearing, perhaps as the result of recent planetesimal collisions. While a spherical clump of optically thin dust can reproduce the contrast seen at L′, it cannot match the observed fluxes across wavelength. The flux from within the disk clearing increases with increasing wavelength, while dust opacities decrease with increasing wavelength. Additionally, the Hα detection also argues against scattering since the dust opacity at Hα and in the nearby continuum should be equal. Thus, subtracting the continuum image from the Hα image would lead to a non-detection in the case of scattered light. Lastly, observing such a collision would be unlikely, since it would shear out on the viscous timescale, which at 10 AU is $\sim$ 3% the age of LkCa 15. Since thermal emission due to heating from neither LkCa 15 A or any of the companions cannot reproduce the observed contrasts, the multiple-planet scenario provides the most natural explanation for the observations.

Continued monitoring of LkCa 15 will provide tighter orbital constraints for LkCa 15 b, c, and d. Additionally, future observations of accretion tracers such as Hα will show whether this accretion is steady or variable. Lastly, the LBT data presented in Sallum et al. 2015a were taken in single-aperture mode - using both LBT primaries independently for $\sim$ 8 m resolution. Future co-phased LBTI observations will nearly triple this resolution, yielding the most detailed infrared view of this forming planetary sys-

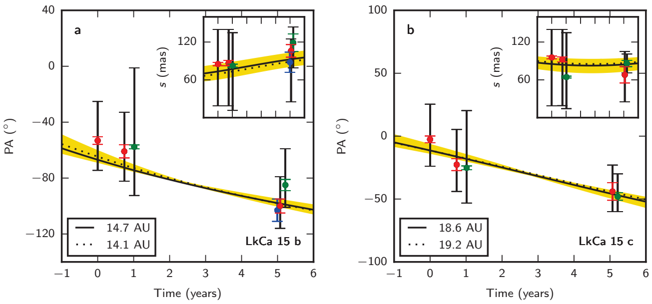

Figure 3: From Sallum et al. (2015a) a) Best fit companion position angles and separations (inset) for LkCa 15 b from 2009-2015, with L′ in red, Ks in green, and Hα in blue. The first three points show 2009-2010 Keck observations, and others show LBT and MagAO data. The colored error bars were derived using the Levenberg-Marquardt algorithm MPFIT (Marquardt 2009) following Kraus & Ireland (2012), while the black error bars were estimated using a grid. The yellow shading corresponds to the 1σ error in the orbital fit, the solid curves show stable orbits for 0.5 Jupiter mass planets, and the dashed curves for 1.0 Jupiter mass planets.

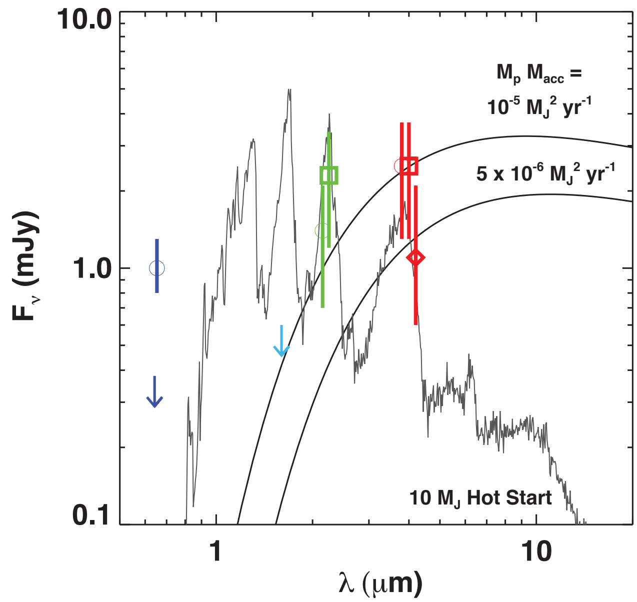

Figure 4: From Sallum et al. 2015a. Colored points show fluxes derived from L′ (red), Ks (green), H (light blue; Ireland & Kraus 2014), and Hα (dark blue). Circles indicate LkCa 15 b, squares LkCa 15 c, and diamonds LkCa 15 d. The light blue arrow shows a previously-published H-band upper limit on all emission within the disk gap (Ireland & Kraus 2014). The dark blue arrow shows the upper limit for Hα flux from LkCa 15 c. Smooth curves show circumplanetary accretion disk models (Eisner 2015), and the spectrum shows a 10 M_J hot-start (Spiegel & Burrows 2012) model.

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Perspective

Insights Into Dense Cores from the JCMT Gould Belt Survey

Helen Kirk

1 Introduction

During the process of forming a star, material must be gathered from the lower density, large size scales of giant molecular clouds (and prior to that, the interstellar medium) into denser, more compact structures. Dense cores, as the hosts and direct progenitors of protostars, have long been of interest as a key phase in star formation (e.g., the Dense Cores in Dark Clouds paper series, starting with Myers et al. 1983). This earlier work has provided a fundamental basis for understanding dense cores as thermally dominated, compact (∼0.1 pc), dense ($\rho \geq 10^4$ cm^{-3}) structures that appear to be in approximate equilibrium (summarized in Di Francesco et al. 2007 and Ward-Thompson et al. 2007a). Dense cores are typically found in the higher column density regions within a molecular cloud, and, like stars, are usually not found in isolation. Over the past decade and a half, studies of dense cores have increasingly turned toward larger, unbiased samples across multiple molecular clouds (e.g., Ridge et al. 2006), in part out of the recognition that environmental factors (such as ambient ionizing radiation) could be a significant factor that needs to be accounted for in interpreting data.

The molecular clouds in the Gould Belt have become an increasingly popular target for multi-wavelength studies. This choice is primarily driven by the close proximity of the Gould Belt clouds. Located only some 100 pc to 500 pc away, the Jeans length (gravitational fragmentation scale) can be resolved by single-dish facilities such as the JCMT. Comprehensive surveys of the Gould Belt include the *Spitzer* c2d and Gould Belt Surveys (Evans et al. 2003, 2009; Dunham et al. 2015; Allen et al. in prep), the *Herschel* Gould Belt Survey (André et al. 2010), and the JCMT Gould Belt Survey (Ward-Thompson et al. 2007b). The combination of data from all three of these facilities is especially powerful, allowing different components of the star-formation process to be separately identified and analyzed, from young protostars and hot or warm dust, to cold material that has not yet formed a protostar. Figure 1 shows a composite image of the L1688 region in Ophiuchus using a combination of *Spitzer*, *Herschel*, and JCMT SCUBA-2 data.

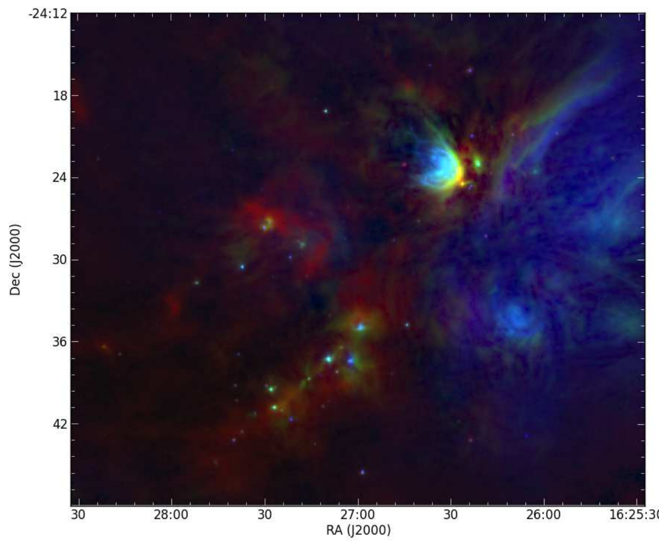

Figure 1: A composite image of the L1688 complex in the Ophiuchus molecular cloud. Red shows emission detected by SCUBA-2 at 850 μm, while green shows 70 μm emission measured by *Herschel* and blue shows 8 μm emission from *Spitzer*. Image credit: JCMT/Herschel Gould Belt Surveys/Spitzer c2d Survey/Pattle et al. 2015/ Image created by R. Friesen.

The JCMT Gould Belt Survey (GBS) consists of two components - large-scale mapping of dust thermal emission in continuum bands centred at 850 μm and 450 μm using SCUBA-2, and smaller maps of CO emission (primarily ^{12}CO(3–2) but also smaller areas of ^{13}CO(3–2) and C^{18}O(3–2)) from the gas present alongside the dust. Figure 2 shows an example of JCMT GBS data, with the left panel showing the full map of the NGC 2023/2024 cluster-forming region in Orion B first presented in Kirk et al. (2016a), and the smaller area of CO mapped with HARP (from Buckle et al. 2010) shown with the red contour.

CO freezes out in the coldest and densest parts of a molecular cloud, so dense cores often show a significantly depleted CO level (e.g., Tafalla et al. 2002), while the am-

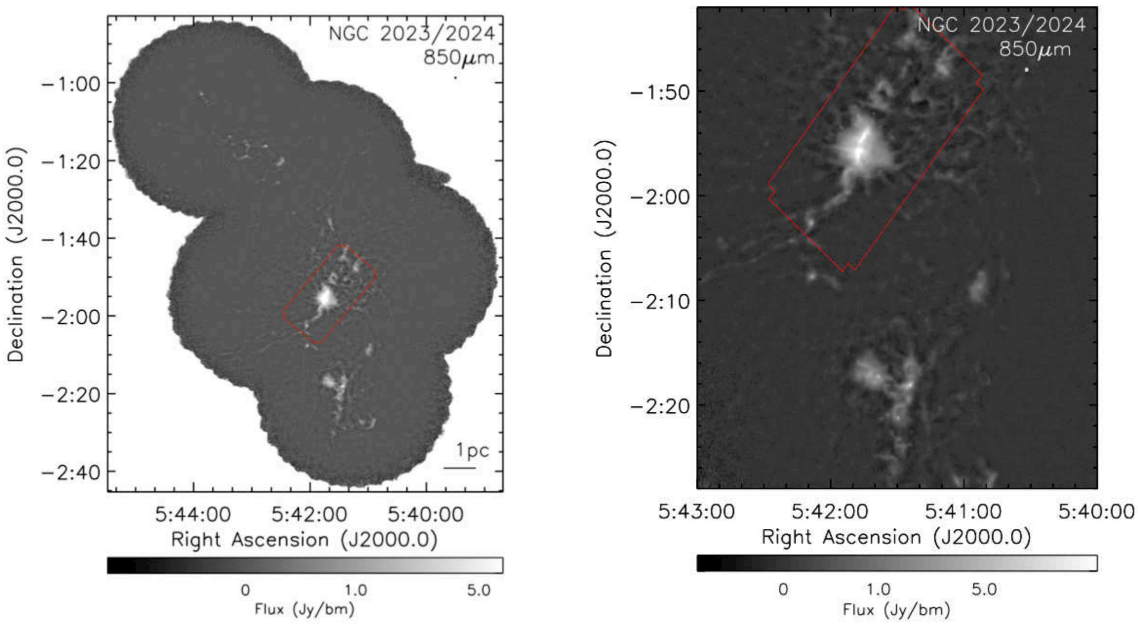

Figure 2: SCUBA-2 850 μm emission in the NGC 2023/2024 part of Orion B. The left panel shows the full area mapped and the HARP CO mapping area is shown with the red contour. The right panel shows a close-up of to the region of most complex emission. A distance of 415 pc is assumed for the linear scale bar shown. Figure from Kirk et al. (2016a).

bient cloud retains a higher abundance of CO in the gas phase. CO is thus typically used to trace bulk gas properties or protostellar outflows. Interested readers can find more information on results from the HARP-based CO analysis of the JCMT GBS in Buckle et al. (2010, 2012), Graves et al. (2010), Davis et al. (2010), Duarte-Cabral et al. (2010), Christie et al. (2012), White et al. (2015), and Drabek-Maunder et al. (2016). The remainder of this article focuses on two exciting highlights from the first set of analyses of the GBS SCUBA-2 data, namely the stability of dense cores and their clustering properties.

2 Stability

One key question concerning dense cores is their stability: are cores stable or bound, are they already collapsing, or are they likely to collapse in the future? The large areas mapped by the JCMT GBS provide measurements of core masses and sizes across a wide variety of environments, providing some pieces to this puzzle.

In the southern part of Orion A, Mairs et al. (submitted) analyze the properties of both the densest peaks and larger-scale structures ('islands') that they live within, with both traced by SCUBA-2 850 μm emission. In their analysis, they find that the most concentrated of peaks tend to be the most Jeans-unstable, with a higher tendency to harbour a protostar already. On larger scales, islands which have already fragmented into multiple dense peaks have a strong tendency to be those which are Jeans unstable.

A full stability analysis of dense cores requires kinematic information in addition to the properties discernable with SCUBA-2 or other continuum observations. Earlier work, for example, Kirk et al. (2007) and Lada et al. (2008), presented evidence that pressure from ambient cloud material on dense cores (i.e., 'external pressure') could be an important factor in core stability. The JCMT GBS allows for this analysis to be performed over much larger populations of dense cores, and in the regions examined so far, external pressure appears to be significant.

Pattle et al. (2015) analyze the dense core population in the Ophiuchus molecular cloud, measuring core masses and sizes from the JCMT GBS data. They supplement this core catalogue with *Herschel* observations to estimate core temperatures, and to help determine which of the cores already harbour protostars. Additionally, they use archival IRAM N_2H^+ observations to measure the nonthermal motions within each core and JCMT GBS HARP $C^{18}O$ observations to estimate the external pressure on each core. Figure 3 shows the results of this analysis, with the cores' virial stability shown on the horizontal axis and the relative importance of gravity and external pressure shown on the vertical axis. As can be clearly seen in the figure, Pattle et al. (2015) find that the majority of dense cores are virially bound (most points lie in the right half of the plot), and the majority of this binding arises from the external pressure (most points lie in the bottom half of the plot). Dense cores in Cepheus (Pattle et al. 2016, in prep) show a similar behaviour.

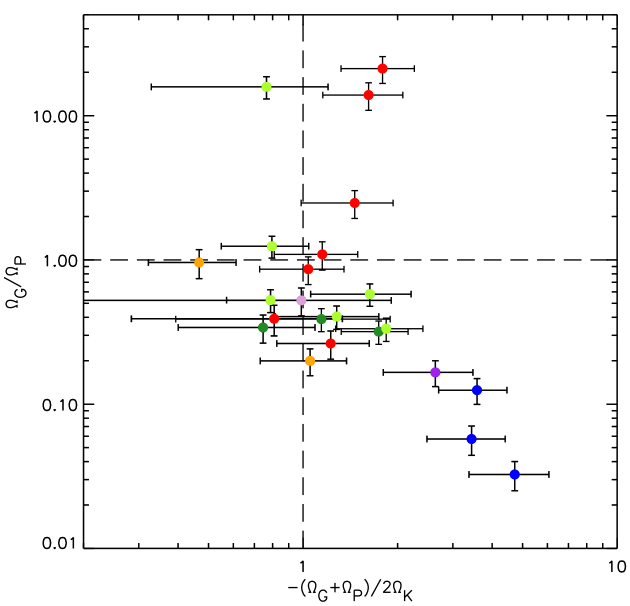

Figure 3: A comparison of the relative importance of gravity, external pressure, and non-thermal motions in dense cores in the Ophiuchus molecular cloud. The vertical axis shows the ratio of the contribution of gravity and external pressure in the virial equation with gravitationally bound cores lying above a ratio of one and pressure-bound cores lying below one. The horizontal axis shows the measure of virial equilibrium, with cores lying to the right of one being virially bound. The different colours mark different sub-regions within Ophiuchus. Figure from Pattle et al. (2015).

In Orion B, Kirk et al. (2016a) lack the spectral data needed in order to perform a full virial analysis, but are still able to calculate some of the quantities of interest. Kirk et al. (2016a) use a total column density map from Lombardi et al. (2014) to estimate the external pressure on the cores, and identify protostellar cores using the *Spitzer*-based catalogue of Megeath et al. (2012) and the *Herschel*-based catalogue of Stutz et al. (2013). In their analysis, the external pressure also appears to be the dominant mechanism keeping the cores bound. Similar analyses have yet to be performed in other GBS clouds. If this tendency is true for all of the clouds, this will have interesting implications on the ability of an environment to form stars.

3 Clustering

The large sample of dense cores being discovered by the GBS also opens a new window into understanding the formation and evolution of clustered systems. As the progenitors of YSOs, groupings of dense cores offer an early view into the primordial conditions of stellar clusters. One particularly controversial topic in the field of cluster formation is whether mass segregation in clusters is primordial or due to early dynamical evolution. Existing observations suggest that stellar mass segregation in clusters is present in at least some systems as early as the class I stage (Elmegreen et al. 2014, Kryukova et al. 2012). Kirk et al. (2016b, in press) and Lane et al. (2016, in prep) provide the first analyses which wind the clock back even further to the dense core stage. Although there is not likely a one-to-one correspondence between dense cores and YSOs, it is reasonable to assume that the more massive YSOs likely form from the more massive dense cores, and this assumption is enough to allow for an exploration of dense core clustering properties to be tied into the stellar stage. Kirk et al. (2016b) analyze the dense core population in cluster-forming regions within the Orion B molecular cloud, and find two independent lines of evidence suggesting that the dense cores are themselves mass segregated. The first line of evidence uses the Minimum Spanning Tree method (Cartwright & Whitworth 2004; Gutermuth et al. 2009) to identify clusters of dense cores. Following a similar analysis of young stellar clusters in Kirk & Myers (2011), Kirk et al. show that the most massive dense core within each of these clusters has a strong tendency to be centrally located. Figure 4 shows the ratio of the angular offset of the most-massive cluster member from the cluster centre, compared to the median angular offset of all cluster members. A set of clusters where the most massive member was randomly located would have an equal number of clusters with offset ratios above and below one, while the Orion B clusters clearly have an over-abundance of small offset ratios. Similar analysis of clusters of cores in Orion A (Lane et al. 2016, in prep) also shows that the most massive cores are centrally located. Both Orion A and B dense core clusters also show a similar distribution in the offset ratios as those seen in a comparable analysis of young *stellar* clusters by Kirk & Myers (2011).

A second metric that can be used to look for the presence of mass segregation in clusters which has the advantage of not requiring clusters to be explicitly identified, is the $M - \Sigma$ technique proposed by Maschberger & Clarke (2011). Here, the local surface density of sources is used as a proxy for the degree of clustering. Hence, mass segregation manifests itself as a tendency for more massive sources to be found at higher local surface densities of sources. Figure 5 shows a comparison of the dense core total flux versus the local core-core surface density in one of the three zones mapped in Orion B by SCUBA-2, NGC 2068/2071. The solid red and blue lines indicate the mean and median values over a co-moving window, highlighting the underlying trend. Although the scatter is large, Kirk et al. (2016b) find strong statistical significance to the overall result that higher mass cores live in more highly clustered environments. Results of an analysis in Orion A (Lane et al. 2016, in prep) are also similar.

These two lines of analyses in both Orion A and B therefore provide intriguing evidence that mass segregation of clusters may be at least partially primordial in nature. Within the GBS, the next step is to determine whether this dense core clustering property is universal or only restricted to special environments like Orion. Looking at the bigger picture, these Orion results underline the importance of understanding how dense cores form, and whether the local (cluster) environment plays a role in their masses.

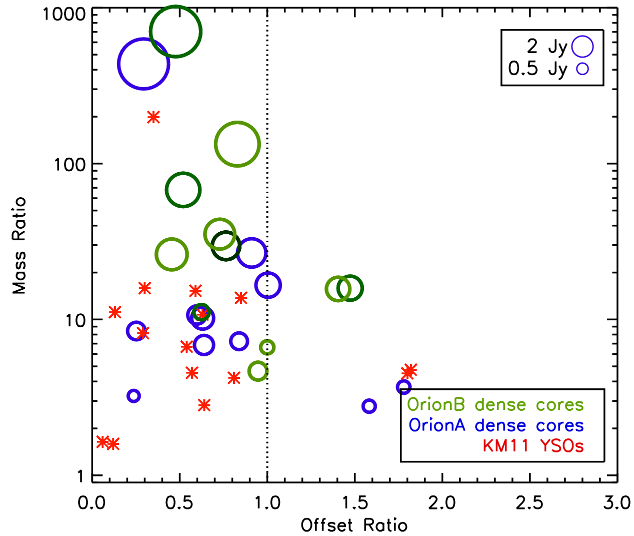

Figure 4: The ratio of the offset from the cluster centre of the most massive cluster member to the median offset of all cluster members. Offset ratios of less than one indicate a centrally located most massive cluster member. Results from dense core cluster analyses in Orion B are shown by the green circles (Kirk et al. 2016b), while the blue circles show a similar analysis of Orion A dense core clusters (Lane et al. 2016, in prep), and the red asterisks show results for nearby young stellar clusters (Kirk & Myers, 2011). Mass segregation manifests as a tendency for offset ratios of less than one. Figure from Kirk et al. (2016b).

4 Other Topics

The SCUBA-2 portion of the JCMT GBS has also made contributions to other areas of research not covered in this short perspective. One major area is the characterization of the spectral energy distribution across extended structures in the star-forming regions. Particularly when combined with *Herschel* GBS data, strong constraints can be made on the distribution of dust temperatures and grain sizes (e.g., the analysis in Perseus by Sadavoy et al. 2013 and Chen et al. 2016, submitted). This information is key to understanding the environment in which dense cores are formed, as well as how to interpret emission when only one wavelength is available (Chen et al., for example, demonstrate that column density estimates in Perseus are typically about 50% too high when standard assumptions are used in the flux-to-mass conversion). Even without *Herschel* data, aspects such as local radiative heating by massive stars can be studied using only the 450 μm to 850 μm ratio, as seen in analyses of Perseus (NGC 1333 by Hatchell et al. 2013) and Serpens (MWC 297 by Rumble et al. 2015 and W40 by Rumble et al. 2016, submitted). An analysis of the effect of CO emission in interpreting the 450 μm and 850 μm flux ratios in Orion A is given by Coudé et al. (2016).

Dense cores often form in filamentary systems, and the study of filaments is a booming new field of research driven largely by spectacular results from the *Herschel* GBS (see André et al. 2014, as well as the Perspective article by J. Di Francesco in issue 252 of the Star Formation Newsletter). The JCMT GBS can provide an interesting view of filaments, with a spatial resolution several times better than *Herschel*'s at long wavelengths. Salji et al. (2015b) present an analysis of filaments in Orion A, and find some intriguing differences from *Herschel*-based analyses such as Arzoumanian et al. (2011), including a larger range of filament widths.

The distribution of the masses of starless dense cores and the similarity between the core mass function and the initial stellar mass function is another much-studied area using a variety of facilities. The JCMT GBS has so far presented dense core mass functions in Ophiuchus (Pattle et al. 2015), the northern portion of Orion A (Salji et al. 2015a), Orion B (Kirk et al. 2016a), and Cepheus (Pattle et al. 2016, in prep).

Finally, the JCMT GBS can provide useful longer wavelength measurements needed to model the spectral energy distribution of protostellar disks. Addition of JCMT GBS

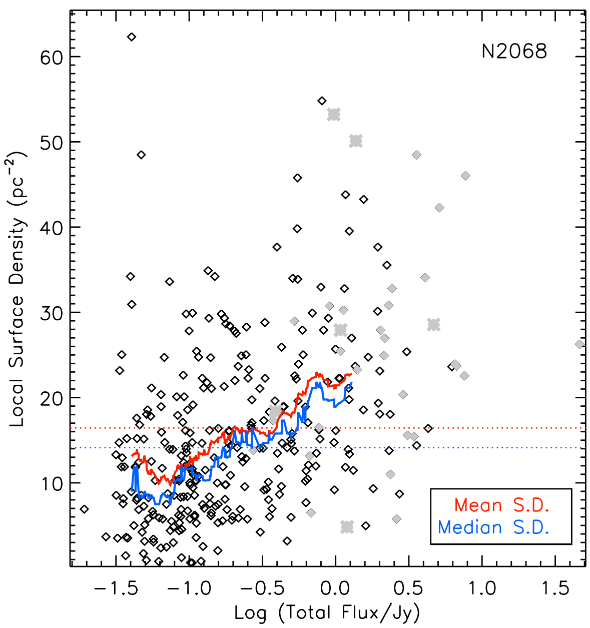

Figure 5: A comparison of dense core flux to the local core-core surface density for the NGC 2068/2071 region in Orion B. The red and blue lines show the mean and median surface density over a co-moving window of twenty sources. The grey diamonds and asterisks denote protostellar cores as found by associations with *Spitzer* (Megeath et al. 2012) and *Herschel* (Stutz et al. 2013) data respectively. Figure from Kirk et al. (2016b).

data to *Spitzer*- or *Herschel*- identified sources can help to determine more accurately the temperatures and masses of the protostellar disks. Current JCMT GBS analyses of disks include NGC 1333 (Dodds et al. 2015), Taurus L1495 (Buckle et al. 2015), and Auriga-California (Broekhoven-Fiene et al. 2016, submitted).

5 Future Directions

Data aquisition for the JCMT GBS finished at the end of January 2015, and survey members have been busy working on the optimal data reduction strategy (see Mairs et al. 2015 for a discussion of some of the issues involved) and the first analysis of each star-forming region covered. The JCMT GBS policy is that the publication of the first paper on any given star-forming region requires a public release of all data products associated with that analysis, and we hope that these data will be widely used in the larger community. Clearly, the surface has barely been scratched for interesting science that is possible with the JCMT GBS data. Survey members are just beginning to work on multi-region analyses looking at all of the measures described here and more, to understand the influence of environment on dense core properties. Please stay tuned!

6 Acknowledgements

The analyses discussed here involved contributions from members across the JCMT GBS Consortium, including input on a draft version of this article.

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Abstracts of recently accepted papers

The very low-mass stellar content of the young supermassive Galactic star cluster Westerlund 1

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We present deep near-infrared HST/WFC3 observations of the young supermassive Galactic star cluster Westerlund 1 and an adjacent control field. The depth of the data is sufficient to derive the mass function for the cluster as a function of radius down to 0.15 $M_\odot$ in the outer parts of the cluster. We identify for the first time a flattening in the mass function (in logarithmic units) at a mass range that is consistent with that of the field and nearby embedded clusters. Through log-normal functional fits to the mass functions we find the nominal peak mass to be comparable to that of the field and nearby embedded star clusters. The width of a log-normal fit appears slightly narrow compared to the width of the field IMF, closer to the values found for globular clusters. The subsolar content within the cluster does not appear to be mass segregated in contrast to the findings for the supersolar content. The total mass of Westerlund 1 is estimated to be 44–57 $\times$ 10^3 $M_\odot$ where the main uncertainty is the choice of the isochrone age and the higher mass slope. Comparing the photometric mass with the dynamically determined mass, Westerlund 1 is sufficiently massive to remain bound and could potentially evolve into a low-mass globular cluster.

Accepted by A&A

http://arxiv.org/pdf/1602.05918

Wind Dynamics and Circumstellar Extinction Variations in the T Tauri Star RY Tau

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The wind interaction with the dusty environment of the classical T Tauri star RY Tau has been investigated. During two seasons of 2013-2015 we carried out a spectroscopic and photometric (BVR) monitoring of the star. A correlation between the stellar brightness and the radial velocity of the wind determined from the Hα and Na D line profiles has been found for the first time. The irregular stellar brightness variations are shown to be caused by extinction in a dusty disk wind at a distance of about 0.2 AU from the star. We suppose, that variations of the circumstellar extinction results from cyclic rearrangements of the stellar magnetosphere and coronal mass ejections, which affect the dusty disk wind near the inner boundary of the circumstellar disk.

Accepted by Astronomy Letters

http://arXiv.org/pdf/1602.04665

Widespread deuteration across the IRDC G035.39-00.33

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Infrared Dark Clouds (IRDCs) are cold, dense regions that are usually found within Giant Molecular Clouds (GMCs). Ongoing star formation within IRDCs is typically still deeply embedded within the surrounding molecular gas. Characterising the properties of relatively quiescent IRDCs may therefore help us to understand the earliest phases of the star formation process. Studies of local molecular clouds have revealed that deuterated species are enhanced in the earliest phases of star formation. In this paper we test this towards IRDC G035.39-00.33. We present an 80 arcsec by 140 arcsec map of the $J = 2 \rightarrow 1$ transition of N_2D^+, obtained with the IRAM-30m telescope. We find that N_2D^+ is widespread throughout G035.39-00.33. Complementary observations of N_2H^+ $(1-0)$ are used to estimate the deuterium fraction, $D_{\rm frac}^{N_2H^+} \equiv N(N_2D^+)/N(N_2H^+)$. We report a mean $D_{\rm frac}^{N_2H^+} = 0.04 \pm 0.01$, with a maximum of $D_{\rm frac}^{N_2H^+} = 0.09 \pm 0.02$. The mean deuterium fraction is ~ 3 orders of magnitude greater than the interstellar [D]/[H] ratio. High angular resolution observations are required to exclude beam dilution effects of compact deuterated cores. Using chemical modelling, we find that the average observed values of the deuterium fraction are in agreement with an equilibrium deuterium fraction, given the general properties of the cloud. This implies that the IRDC is at least ~ 3 Myr old, which is ~ 8 times longer than the mean free-fall time of the observed deuterated region.

Accepted by MNRAS

http://arxiv.org/pdf/1602.06798v1.pdf

Influence of the water content in protoplanetary discs on planet migration and formation

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The temperature and density profiles of protoplanetary discs depend crucially on the mass fraction of micrometre-sized dust grains and on their chemical composition. A larger abundance of micrometre-sized grains leads to an overall heating of the disc, so that the water ice line moves further away from the star. An increase in the water fraction inside the disc, maintaining a fixed dust abundance, increases the temperature in the icy regions of the disc and lowers the temperature in the inner regions. Discs with a larger silicate fraction have the opposite effect. Here we explore the consequence of the dust composition and abundance for the formation and migration of planets. We find that discs with low water content can only sustain outwards migration for planets up to 4 Earth masses, while outwards migration in discs with a larger water content persists up to 8 Earth masses in the late stages of the disc evolution. Icy planetary cores that do not reach run-away gas accretion can thus migrate to orbits close to the host star if the water abundance is low. Our results imply that hot and warm super-Earths found in exoplanet surveys could have formed beyond the ice line and thus contain a significant fraction in water. These water-rich super-Earths should orbit primarily around stars with a low oxygen abundance, where a low oxygen abundance is caused by either a low water-to-silicate ratio or by overall low metallicity.

Accepted by A&A

http://arxiv.org/pdf/1603.01125

Variability in young very low mass stars: Two surprises from spectrophotometric monitoring

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We present simultaneous photometric and spectroscopic observations of seven young and highly variable M dwarfs in star forming regions in Orion, conducted in 4 observing nights with FORS2 at ESO/VLT. All seven targets show significant photometric variability in the I-band, with amplitudes between 0.1-0.8 mag. The spectra, however, remain remarkably constant, with spectral type changes less than 0.5 subtypes. Thus, the brightness changes are not caused by veiling that 'fills in' absorption features. Three objects in the σ Ori cluster (age ∼3 Myr) exhibit strong H? emission and H? variability, in addition to the continuum variations. Their behavior is mostly consistent with the presence of spots with temperature of ∼300 K above the photosphere and filling factors between 0.2-0.4, in contrast to typical hot spots observed in more massive stars. The remaining targets near ϵ Ori, likely to be older, show eclipse-like lightcurves, no significant Hα activity and are better represented by variable extinction due to circumstellar material. Interestingly, two of them show no evidence of infrared excess emission. Our study shows that high-amplitude variability in young very low mass stars can be caused by different phenomena than in more massive T Tauri stars and can persist when the disk has disappeared and accretion has ceased.

Accepted by MNRAS

http://arxiv.org/pdf/1602.07925

On the origins of polarization holes in Bok globules

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Context. Polarimetric observations of Bok globules frequently show a decrease in the degree of polarization towards their central dense regions (polarization holes). This behaviour is usually explained with increased disalignment owing to high density and temperature, or insufficient angular resolution of a possibly complex magnetic field structure.
em Aims. We investigate whether a significant decrease in polarized emission of dense regions in Bok globules is possible under certain physical conditions. For instance, we evaluate the impact of optical depth effects and various properties of the dust phase.
Methods. We use radiative transfer modelling to calculate the temperature structure of an analytical Bok globule model and simulate the polarized thermal emission of elongated dust grains. For the alignment of the dust grains, we consider a magnetic field and include radiative torque and internal alignment.
Results. Besides the usual explanations, selected conditions of the temperature and density distribution, the dust phase and the magnetic field are also able to significantly decrease the polarized emission of dense regions in Bok globules. Taking submm/mm grains and typical column densities of existing Bok globules into consideration, the optical depth is high enough to decrease the degree of polarization by up to ΔP∼10%. If limited to the densest regions, dust grain growth to submm/mm size and accumulated graphite grains decrease the degree of polarization by up to ΔP∼10% and ΔP∼5%, respectively. However, the effect of the graphite grains occurs only if they do not align with the magnetic field.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/1603.00270

The First Brown Dwarf/Planetary-Mass Object in the 32 Orionis Group

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The 32 Orionis group is a co-moving group of roughly 20 young (24 Myr) M3-B5 stars 100 pc from the Sun. Here we report the discovery of its first substellar member, WISE J052857.69+090104.2. This source was previously reported to be an M giant star based on its unusual near-infrared spectrum and lack of measurable proper motion. We re-analyze previous data and new moderate-resolution spectroscopy from Magellan/FIRE to demonstrate that this source is a young near-infrared L1 brown dwarf with very low surface gravity features. Spectral model fits indicate $T_{\rm eff} = 1880^{+150}_{-70}$ K and $\log g = 3.8^{+0.2}_{-0.2}$ (cgs), consistent with a 15–22 Myr object with a mass near the deuterium-burning limit. Its sky position, estimated distance, kinematics (both proper motion and radial velocity), and spectral characteristics are all consistent with membership in 32 Orionis, and its temperature and age imply a mass ($M = 14^{+4}_{-3}\ M_{\rm Jup}$) that straddles the brown dwarf/planetary-mass object boundary. The source has a somewhat red J−W2 color compared to other L1 dwarfs, but this is likely a low-gravity-related temperature offset; we find no evidence of significant excess reddening from a disk or cool companion in the 3–5 μm waveband.

Accepted by ApJ

http://arxiv.org/pdf/1602.03022

Resolved observations of transition disks

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Resolved observations are bringing new constraints on the origin of radial gaps in protoplanetary disks. The kinematics, sampled in detail in one case-study, are indicative of non-Keplerian flows, corresponding to warped structures and accretion which may both play a role in the development of cavities. Disk asymmetries seen in the radio continuum are being interpreted in the context of dust segregation via aerodynamic trapping. We summarise recent observational progress, and also describe prospects for improvements in the near term.

Accepted by PASA

http://arxiv.org/pdf/1602.06523

Origin of the Lyman excess in early-type stars

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Ionized regions around early-type stars are believed to be well-known objects, but until recently, our knowledge of the relation between the free-free radio emission and the IR emission has been observationally hindered by the limited angular resolution in the far-IR. The advent of *Herschel* has now made it possible to obtain a more precise comparison between the two regimes, and it has been found that about a third of the young HII regions emit more Lyman continuum photons than expected, thus presenting a Lyman excess. With the present study we wish to distinguish between two scenarios that have been proposed to explain the existence of the Lyman excess: (i) underestimation of the bolometric luminosity, or (ii) additional emission of Lyman-continuum photons from an accretion shock. We observed an outflow (SiO) and an infall (HCO^+) tracer toward a complete sample of 200 HII regions, 67 of which present the Lyman excess. Our goal was to search for any systematic difference between sources with Lyman excess and those without. While the outflow tracer does not reveal any significant difference between the two subsamples of HII regions, the infall tracer indicates that the Lyman-excess sources are more associated with infall signposts than the other objects. Our findings indicate that the most plausible explanation for the Lyman excess is that in addition to the Lyman continuum emission from the early-type star, UV photons are emitted from accretion shocks in the stellar neighborhood. This result suggests that high-mass stars and/or stellar clusters containing young massive stars may continue to accrete for a long time, even after the development of a compact HII region.

Accepted by Astronomy and Astrophysics Letter

http://www.arcetri.astro.it/science/starform/preprints/cesa_27.pdf

Rotating Bullets from a Variable Protostar

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We present SMA CO (2–1) observations toward the protostellar jet driven by SVS13A, a variable protostar in the NGC1333 star-forming region. The SMA CO (2–1) images show an extremely high-velocity jet composed of a series of molecular 'bullets'. Based on the SMA CO observations, we discover clear and large systematic velocity gradients, perpendicular to the jet axis, in the blueshifted and redshifted bullets. After discussing several alternative interpretations, such as twin-jets, jet precession, warped disk, and internal helical shock, we suggest that the systematic velocity gradients observed in the bullets result from the rotation of the SVS13A jet. From the SMA CO images, the measured rotation velocities are 11.7–13.7 km s^{-1} for the blueshifted bullet and 4.7±0.5 km s^{-1} for the redshifted bullet. The estimated specific angular momenta of the two bullets are comparable to those of dense cores, about 10 times larger than those of protostellar envelopes, and about 20 times larger than those of circumstellar disks. If the velocity gradients are due to the rotation of the SVS13A jet, the significant amount of specific angular momenta of the bullets indicates that the rotation of jets/outflows is a key mechanism to resolve the so-called 'angular momentum problem' in the field of star formation. The kinematics of the bullets suggests that the jet launching footprint on the disk has a radius of about 7.2–7.7 AU, which appears to support the extended disk-wind model. We note that further observations are needed to comprehensively understand the kinematics of the SVS13A jet, in order to confirm the rotation nature of the bullets.

Accepted by ApJ

http://arxiv.org/pdf/1602.06350

Submillimeter Array Observations of NGC 2264-C: Molecular Outflows and Driving Sources

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We present 1.3 mm Submillimeter Array (SMA) observations at ∼3" resolution towards the brightest section of the intermediate/massive star forming cluster NGC 2264-C. The millimetre continuum emission reveals ten 1.3 mm continuum peaks, of which four are new detections. The observed frequency range includes the known molecular jet/outflow tracer SiO (5-4), thus providing the first high resolution observations of SiO towards NGC 2264-C. We also detect molecular lines of twelve additional species towards this region, including CH_3CN, CH_3OH, SO, H_2CO, DCN, HC_3N, and ^{12}CO. The SiO (5-4) emission reveals the presence of two collimated, high velocity (up to $30\,km\,s^{-1}$ with respect to the systemic velocity) bi-polar outflows in NGC 2264-C. In addition, the outflows are traced by emission from ^{12}CO, SO, H_2CO, and CH_3OH. We find an evolutionary spread between cores residing in the same parent cloud. The two unambiguous outflows are driven by the brightest mm continuum cores, which are IR-dark, molecular line weak, and likely the youngest cores in the region. Furthermore, towards the RMS source AFGL 989-IRS1, the IR-bright and most evolved source in NGC 2264-C, we observe no molecular outflow emission. A molecular line rich ridge feature, with no obvious directly associated continuum source, lies on the edge of a low density cavity and may be formed from a wind driven by AFGL 989-IRS1. In addition, 229 GHz class I maser emission is detected towards this feature.

Accepted by MNRAS

http://arxiv.org/pdf/1602.06196

Two confirmed class I very low-mass objects in Taurus

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[GKH94] 41 and IRAS 04191+1523B were previously identified to be proto-brown dwarf candidates in Taurus. [GKH94] 41 was classified to be a class I object. The dereddened spectral energy distribution of the source was later found to be suggestive of a class II object. IRAS 04191+1523B is a class I object that is the secondary component of a binary. We determine the evolutionary stage of [GKH94] 41 and estimate the final masses of the two proto-brown dwarf candidates. We used archive millimeter observations to produce continuum maps and collected data from the literature to construct the spectral energy distribution of the targets. Our continuum maps revealed that both [GKH94] 41 and IRAS 04191+1523B are surrounded by envelopes. This provides direct evidence that [GKH94] 41 is a class I object, not class II, as previously classified. For IRAS 04191+1523B, our continuum map spatially resolved the binary. Our estimated final masses are below $49^{+56}_{-27}\ M_{\rm J}$ and $75^{+40}_{-26}\ M_J$ for [GKH94] 41 and IRAS 04191+1523B, respectively. This indicates that both sources will likely become brown dwarfs or very low-mass stars. Therefore, [GKH94] 41 and IRAS 04191+1523B are two new confirmed class I very low-mass objects. Their existence also supports the scenario that brown dwarfs have the same formation stages as low-mass stars.

Accepted by A&A Letters

http://arxiv.org/pdf/1602.06357

The inner structure of the TW Hya Disk as revealed in scattered light

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We observe a significant change in the TW Hya disk interior to 40 AU via archival unpolarized multi-wavelength Hubble Space Telescope/STIS and NICMOS images with an inner working angle (IWA) of $0\farcs4$ (22 AU). Our images show the outer edge of a clearing at every wavelength with similar behavior, demonstrating that the feature is structural, rather than due to some property of polarized light in the disk. We compare our observations to those taken by Akiyama et al. (2015) and Rapson et al. (2015), and discuss the spectral evolution of the disk interior to 80 AU. We construct a

model with two gaps: one at 30 AU and one at 80 AU that fit the observed surface brightness profile but overpredicts the absolute brightness of the disk. Our models require an additional dimming to be consistent with observations, which we tentatively ascribe to shadowing. The gap structures seen in scattered light are spatially coincident with sub-mm detections of CO and N_2H^+, and are near expected condensation fronts of these molecular species, providing tentative evidence that the structures seen in scattered light may be correlated with chemical changes in the disk.

Accepted by ApJL

http://arxiv.org/pdf/1602.02090

Two mechanisms for dust gap opening in protoplanetary discs

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We identify two distinct physical mechanisms for dust gap opening by embedded planets in protoplanetary discs based on the symmetry of the drag-induced motion around the planet: I) A mechanism where low mass planets, that do not disturb the gas, open gaps in dust by tidal torques assisted by drag in the inner disc, but resisted by drag in the outer disc; and II) The usual, drag assisted, mechanism where higher mass planets create pressure maxima in the gas disc which the drag torque then acts to evacuate further in the dust. The first mechanism produces gaps in dust but not gas, while the second produces partial or total gas gaps which are deeper in the dust phase. Dust gaps do not necessarily indicate gas gaps.

Accepted by MNRAS Letters

http://arxiv.org/pdf/1602.07457

Variations of accretion rate and luminosity in gravitationally unstable protostellar disks

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In this study, we perform a self-consistent numerical hydrodynamics simulation of a protostar and protostellar disk during the early stages of evolution. The mass accretion rate at a distance of a few astronomical units from the protostar is essentially variable, which is also reflected in the character of protostellar luminosity. The amplitude of luminosity and accretion rate variations in our model increases with the increasing time sampling period, which can be expected for gravitationally unstable protostellar disks. A comparison of the model luminosity variations with those found from observations of nearby star formation regions shows that the model variations are much smaller than the observed ones on timescales less than 10 years. This indicates the presence of additional sources of variability on dynamically small distances from the protostar.

Accepted by Astronomy Reports

The Herschel Orion Protostar Survey: Spectral Energy Distributions and Fits Using a Grid of Protostellar Models

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We present key results from the Herschel Orion Protostar Survey (HOPS): spectral energy distributions (SEDs) and model fits of 330 young stellar objects, predominantly protostars, in the Orion molecular clouds. This is the largest sample of protostars studied in a single, nearby star-formation complex. With near-infrared photometry from 2MASS, mid- and far-infrared data from Spitzer and Herschel, and sub-millimeter photometry from APEX, our SEDs cover 1.2–870 μm and sample the peak of the protostellar envelope emission at $\sim$100 μm. Using mid-IR spectral indices and bolometric temperatures, we classify our sample into 92 Class 0 protostars, 125 Class I protostars, 102 flat-spectrum sources, and 11 Class II pre-main-sequence stars. We implement a simple protostellar model (including a disk in an infalling envelope with outflow cavities) to generate a grid of 30400 model SEDs and use it to determine the best-fit model parameters for each protostar. We argue that far-IR data are essential for accurate constraints on protostellar envelope properties. We find that most protostars, and in particular the flat-spectrum sources, are well-fit. The median envelope density and median inclination angle decrease from Class 0 to Class I to flat-spectrum protostars, despite the broad range in best-fit parameters in each of the three categories. We also discuss degeneracies in our model parameters. Our results confirm that the different protostellar classes generally correspond to an evolutionary sequence with a decreasing envelope infall rate, but the inclination angle also plays a role in the appearance, and thus interpretation, of the SEDs.

Accepted by ApJS

http://arxiv.org/pdf/1602.07314

Multi-dimensional structure of accreting young stars

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This work is the first attempt to describe the multi-dimensional structure of accreting young stars based on fully compressible time implicit multi-dimensional hydrodynamics simulations. One major motivation is to analyse the validity of accretion treatment used in previous 1D stellar evolution studies. We analyse the effect of accretion on the structure of a realistic stellar model of the young Sun. Our work is inspired by the numerical work of Kley & Lin (1996, ApJ, 461, 933) devoted to the structure of the boundary layer in accretion disks, which provides the outer boundary conditions for our simulations. We analyse the redistribution of accreted material with a range of values of specific entropy relative to the bulk specific entropy of the material in the accreting object's convective envelope. Low specific entropy accreted material characterises the so-called cold accretion process, whereas high specific entropy is relevant to hot accretion. A primary goal is to understand whether and how accreted energy deposited onto a stellar surface is redistributed in the interior. This study focusses on the high accretion rates characteristic of FU Ori systems. We find that the highest entropy cases produce a distinctive behaviour in the mass redistribution, rms velocities, and enthalpy flux in the convective envelope. This change in behaviour is characterised by the formation of a hot layer on the

surface of the accreting object, which tends to suppress convection in the envelope. We analyse the long-term effect of such a hot buffer zone on the structure and evolution of the accreting object with 1D stellar evolution calculations. We study the relevance of the assumption of redistribution of accreted energy into the stellar interior used in the literature. We compare results obtained with the latter treatment and those obtained with a more physical accretion boundary condition based on the formation of a hot surface layer suggested by present multi-dimensional simulations. One conclusion is that, for a given amount of accreted energy transferred to the accreting object, a treatment assuming accretion energy redistribution throughout the stellar interior could significantly overestimate the effects on the stellar structure and, in particular, on the resulting expansion

Accepted by Astronomy and Astrophysics

http://arxiv.org/pdf/1602.03325.pdf

Molecular clouds and star formation toward the Galactic plane within 216.5° $\leq l \leq$ 218.75° and −0.75° $\leq b \leq$ 1.25°

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Context: Molecular clouds trace the spiral arms of the Milky Way and all its star forming regions. Large-scale mapping of molecular clouds will provide an approach to understand the processes that govern star formation and molecular cloud evolution.
Aims: As a part of the Milky Way Imaging Scroll Painting (MWISP) survey, the aim is to study the physical properties of molecular clouds and their associated star formation toward the Galactic plane within 216.25°$\leq l \leq$ 218.75°and −0.75°$\leq b \leq$ 1.25°, which covers the molecular cloud complex S287.
Methods: Using the 3×3 Superconducting Spectroscopic Array Receiver (SSAR) at the PMO-13.7m telescope, we performed a simultaneous ^{12}CO (1–0), ^{13}CO (1–0), C^{18}O (1–0) mapping toward molecular clouds in a region encompassing 3.75 square degrees. We also make use of archival data to study star formation within the molecular clouds.
Results: We reveal three molecular clouds, the 15 km s^{-1} cloud, the 27 km s^{-1} cloud, and the 50 km s^{-1} cloud, in the surveyed region. The 50 km s^{-1} cloud is resolved with an angular resolution of $\sim$1′ for the first time. Investigating their morphology and velocity structures, we find that the 27 km s^{-1} cloud is likely affected by feedback from the stellar association Mon OB3 and the 50 km s^{-1} cloud is characterized by three large expanding molecular shells. The surveyed region is mapped in C^{18}O (1–0) for the first time. We discover seven C^{18}O clumps that are likely to form massive stars, and 15 dust clumps based on the Bolocam Galactic Plane Survey (BGPS) archive data. Using infrared color-color diagrams, we find 56 Class I and 107 Class II young stellar object (YSO) candidates toward a slightly larger region of 5.0 square degrees. Based on the distribution of YSO candidates, an overdensity is found around the HII region S287 and the intersection of two shells; this is probably indicative of triggering. The star formation efficiency (SFE) and rate (SFR) of the 27 km s^{-1} cloud are discussed. Comparing the observed values of the filament S287-main with fragmentation models, we suggest that turbulence controls the large-scale fragmentation in the filament, while gravitational fragmentation plays an important role in the formation of YSOs on small scales. We find that star-forming gas tends to have a higher excitation temperature, a higher ^{13}CO (1–0) opacity, and a higher column density than non-star-forming gas, which is consistent with the point that star formation occurs in denser gas and star-forming gas is heated by YSOs. Using the 1.1 mm dust emission to trace dense gas, we obtain a dense gas fraction of 2.7%–10.4% for the 27 km s^{-1} cloud.

Accepted by A&A

http://arxiv.org/pdf/1602.00460

Carbon Chains and Methanol toward Embedded Protostars

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Large interstellar organic molecules are potential precursors of prebiotic molecules. Their formation pathways and chemical relationships with one another and simpler molecules are therefore of great interest. In this paper, we address the relationship between two classes of large organic molecules, carbon chains and saturated complex organic molecules (COMs), at the early stages of star formation through observations of C_4H and CH_3OH. We surveyed these molecules with the IRAM 30m telescope toward 16 deeply embedded low-mass protostars selected from the Spitzer c2d ice survey. We find that CH_3OH and C_4H are positively correlated indicating that these two classes of molecules can coexist during the embedded protostellar stage. The C_4H/CH_3OH gas abundance ratio tentatively correlates with the CH_4/CH_3OH ice abundance ratio in the same lines of sight. This relationship supports a scenario where carbon chain formation in protostellar envelopes begins with CH_4 ice desorption.

Accepted by ApJ

http://arxiv.org/pdf/1602.01472

APOGEE strings: a fossil record of the gas kinematic structure

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We compare APOGEE radial velocities (RVs) of young stars in the Orion A cloud with CO line gas emission and find a correlation between the two at large-scales, in agreement with previous studies. However, at smaller scales we find evidence for the presence of substructure in the stellar velocity field. Using a Friends-of-Friends approach we identify 37 stellar groups with almost identical RVs. These groups are not randomly distributed but form elongated chains or strings of stars with five or more members with low velocity dispersion, across lengths of 1-1.5 pc. The similarity between the kinematic properties of the APOGEE strings and the internal velocity field of the chains of dense cores and fibers recently identified in the dense ISM is striking and suggests that for most of the Orion A cloud, young stars keep memory of the parental gas substructure where they originated.

Accepted by A&A

http://adsabs.harvard.edu/pdf/2016arXiv160201854H

Impact of initial models and variable accretion rates on the pre-main-sequence evolution of massive and intermediate-mass stars and the early evolution of HII regions

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Massive star formation requires the accretion of gas at high rate while the star is already bright. Its actual luminosity depends sensitively on the stellar structure. We compute pre-main-sequence tracks for massive and intermediate-mass stars with variable accretion rates and study the evolution of stellar radius, effective temperature and ionizing luminosity, starting at $2\,M_\odot$ with convective or radiative structures. The radiative case shows a much stronger swelling of the protostar for high accretion rates than the convective case. For radiative structures, the star is very sensitive to the accretion rate and reacts quickly to accretion bursts, leading to considerable changes in photospheric properties on timescales as short as $100 - 1000$ yr. The evolution for convective structures is much less influenced by the instantaneous accretion rate, and produces a monotonically increasing ionizing flux that can be many orders of magnitude smaller than in the radiative case. For massive stars, it results in a delay of the H II region expansion by up to 10,000 yr. In the radiative case, the H II region can potentially be engulfed by the star during the swelling, which never happens in the convective case. We conclude that the early stellar structure has a large impact on the radiative feedback during the pre-main-sequence evolution of massive protostars and introduces an important uncertainty that should be taken into account. Because of their lower effective temperatures, our convective models may hint at a solution to an observed discrepancy between the luminosity distribution functions of massive young stellar objects and compact H II regions.

Accepted by MNRAS

http://arxiv.org/pdf/1603.00332.pdf

Spiral-driven accretion in protoplanetary discs — II Self-similar solutions

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Accretion discs are ubiquitous in the universe and it is a crucial issue to understand how angular momentum and mass are being radially transported in these objects. Here, we study the role played by non-linear spiral patterns within hydrodynamical and non self-gravitating accretion disc assuming that external disturbances such as infall onto the disc may trigger them. To do so, we computed self-similar solutions that describe discs in which a spiral wave propagates. Such solutions present both shocks and critical sonic points that we carefully analyze. For all allowed temperatures and for several spiral shocks, we calculated the wave structure. In particular we inferred the angle of the spiral patern, the stress it exerts on the disc as well as the associated flux of mass and angular momentum as a function of temperature. We quantified the rate of angular momentum transport by means of the dimensionless α parameter. For the thickest disc we considered (corresponding to h/r values of about 1/3), we found values of α as high as 0.1, and scaling with the temperature T such that $\alpha \propto T^{3/2} \propto (h/r)^3$. The spiral angle scales with the temperature as $\arctan(r/h)$. The existence of these solutions suggests that perturbations occurring at disc outer boundaries, such as for example perturbations due to infall motions, can propagate deep inside the disc and therefore should not be ignored, even when considering small radii.

Accepted by A&A

http://arxiv.org/pdf/1602.01721

Star formation in W3 - AFGL333: Young stellar content, Properties and Roles of external feedback

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One of the key questions in the field of star formation is the role of stellar feedback on subsequent star formation process. The W3 giant molecular cloud complex at the western border of the W4 super bubble is thought to be influenced by the stellar winds of the massive stars in W4. AFGL333 is a $\sim 10^4$ $M_\odot$ cloud within W3. This paper presents a study of the star formation activity within AFGL333 using deep JHK_s photometry obtained from the NOAO Extremely Wide-Field Infrared Imager combined with *Spitzer*-IRAC-MIPS photometry. Based on the infrared excess, we identify 812 candidate young stellar objects in the complex, of which 99 are classified as Class I and 713 are classified as Class II sources. The stellar density analysis of young stellar objects reveals three major stellar aggregates within AFGL333, named here AFGL333-main, AFGL333-NW1 and AFGL333-NW2. The disk fraction within AFGL333 is estimated to be $\sim$ 50–60%. We use the extinction map made from the $H - K_s$ colors of the background stars to understand the cloud structure and to estimate the cloud mass. The CO-derived extinction map corroborates the cloud structure and mass estimates from NIR color method. From the stellar mass and cloud mass associated with AFGL333, we infer that the region is currently forming stars with an efficiency of $\sim$ 4.5% and at a rate of $\sim$ 2 - 3 $M_\odot$ Myr^{-1}pc^{-2}. In general, the star formation activity within AFGL333 is comparable to that of nearby low mass star-forming regions. We do not find any strong evidence to suggest that the stellar feedback from the massive stars of nearby W4 super bubble has affected the global star formation properties of the AFGL333 region.

Accepted by ApJ

http://arxiv.org/pdf/1602.06212v1.pdf

Chemical spots on the surface of the strongly magnetic Herbig Ae star HD 101412

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Due to the knowledge of the rotation period and the presence of a rather strong surface magnetic field, the sharp-lined young Herbig Ae star HD 101412 with a rotation period of 42 d has become one of the most well-studied targets among the Herbig Ae stars. High-resolution HARPS polarimetric spectra of HD 101412 were recently obtained on seven different epochs. Our study of the spectral variability over the part of the rotation cycle covered by HARPS observations reveals that the line profiles of the elements Mg, Si, Ca, Ti, Cr, Mn, Fe, and Sr are clearly variable while He exhibits variability that is opposite to the behaviour of the other elements studied. Since classical Ap stars usually show a relationship between the magnetic field geometry and the distribution of element spots, we used in our magnetic field measurements different line samples belonging to the three elements with the most numerous spectral lines, Ti, Cr, and Fe. Over the time interval covered by the available spectra, the longitudinal magnetic field changes sign from negative to positive polarity. The distribution of field values obtained using Ti, Cr, and Fe lines is, however, completely different compared to the magnetic field values determined in previous low-resolution FORS 2 measurements, where hydrogen Balmer lines are the main contributors to the magnetic field measurements, indicating the presence of concentration of the studied iron-peak elements in the region of the magnetic equator. Further, we discuss the potential role of contamination by the surrounding warm circumstellar matter in the appearance of Zeeman features obtained using Ti lines.

Accepted by Astronomical Notes

http://arxiv.org/pdf/1602.03306

VLT/SPHERE deep insight of NGC 3603's core: Segregation or confusion?

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We present new near-infrared photometric measurements of the core of the young massive cluster NGC 3603 obtained with extreme adaptive optics. The data were obtained with the SPHERE instrument mounted on ESO's Very Large Telescope, and cover three fields in the core of this cluster. We applied a correction for the effect of extinction to our data obtained in the J and K broadband filters and estimated the mass of detected sources inside the field of view of SPHERE/IRDIS, which is 13.5"×13.5". We derived the mass function (MF) slope for each spectral band and field. The MF slope in the core is unusual compared to previous results based on Hubble space telescope (HST) and very large telescope (VLT) observations. The average slope in the core is estimated as -1.06 ± 0.26 for the main sequence stars with $3.5\,M_\odot < M < 120\,M_\odot$. Thanks to the SPHERE extreme adaptive optics, 814 low-mass stars were detected to estimate the MF slope for the pre-main sequence stars with $0.6\,M_\odot < M < 3.5\,M_\odot$, $\Gamma = -0.54 \pm 0.11$ in the K-band images in two fields in the core of the cluster. For the first time, we derive the mass function of the very core of the NGC 3603 young cluster for masses in the range 0.6 - 120 $M_\odot$. Previous studies were either limited by crowding, lack of dynamic range, or a combination of both.

Accepted by Astronomy and Astrophysics Letter (AA/2016/28107)

http://arxiv.org/pdf/1603.00457

Searching for spectroscopic binaries within transition disk objects

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Transition disks (TDs) are intermediate stage circumstellar disks characterized by an inner gap within the disk structure. To test whether these gaps may have been formed by closely orbiting, previously undetected stellar companions, we collected high-resolution optical spectra of 31 TD objects to search for spectroscopic binaries (SBs). Twenty-four of these objects are in Ophiuchus and seven are within the Coronet, Corona Australis, and Chameleon I star-forming regions. We measured radial velocities for multiple epochs, obtaining a median precision of 400 m s^{-1}. We identified double-lined SB SSTc2d J163154.7−250324 in Ophiuchus, which we determined to be composed of a K7($\pm$0.5) and a K9($\pm$0.5) star, with orbital limits of $a < 0.6$ AU and $P < 150$ days. This results in an SB fraction of $0.04^{+0.12}_{-0.03}$ in Ophiuchus, which is consistent with other spectroscopic surveys of non-TD objects in the region. This similarity suggests that TDs are not preferentially sculpted by the presence of close binaries and that planet formation around close binaries may take place over similar timescales to that around single stars.

Accepted by ApJ

http://arxiv.org/pdf/1602.07582

An HST Survey for 100-1000 AU Companions around Young Stellar Objects in the Orion Molecular Clouds: Evidence for Environmentally Dependent Multiplicity

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We present a near-IR survey for the visual multiples in the Orion molecular clouds region at separations between

100 and 1000 AU. These data were acquired at 1.6 μm with the NICMOS and WFC3 cameras on the Hubble Space Telescope. Additional photometry was obtained for some of the sources at 2.05 μm with NICMOS and in the L'-band with NSFCAM2 on the IRTF. Towards 129 protostars and 197 pre-main sequence stars with disks observed with WFC3, we detect 21 and 28 candidate companions between the projected separations of 100—1000 AU, of which less than 5 and 8, respectively, are chance line of sight coincidences. The resulting companion fraction (CF) after the correction for the line of sight contamination is $14.4^{+1.1}_{-1.3}$% for protostars and $12.5^{+1.2}_{-0.8}$% for the pre-main sequence stars. These values are similar to those found for main sequence stars, suggesting that there is little variation in the CF with evolution, although several observational biases may mask a decrease in the CF from protostars to the main sequence stars. After segregating the sample into two populations based on the surrounding surface density of YSOs, we find that the CF in the high stellar density regions ($\Sigma_{YSO} > 45$ pc^{-2}) is approximately 50% higher than that found in the low stellar density regions ($\Sigma_{YSO} < 45$ pc^{-2}). We interpret this as evidence for the elevated formation of companions at 100 to 1000 AU in the denser environments of Orion. We discuss possible reasons for this elevated formation.

Accepted by ApJ

http://arxiv.org/pdf/1602.07635

Spectroscopic Binaries in the Orion Nebula Cluster and NGC 2264

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We examine the spectroscopic binary population for two massive nearby regions of clustered star formation, the Orion Nebula Cluster and NGC 2264, supplementing the data presented by Tobin et al. (2009, 2015) with more recent observations and more extensive analysis. The inferred multiplicity fraction up to 10 AU based on these observations is 5.3±1.2% for NGC 2264 and 5.8±1.1% for the ONC; they are consistent with the distribution of binaries in the field in the relevant parameter range. Eight of the multiple systems in the sample have enough epochs to make an initial fit for the orbital parameters. Two of these sources are double-lined spectroscopic binaries; for them we determine the mass ratio. Our reanalysis of the distribution of stellar radial velocities towards these clusters presents a significantly better agreement between stellar and gas kinematics than was previously thought.

Accepted by Apj

http://arxiv.org/pdf/1602.05630

The intermediate-mass star forming region Lynds 1340. An optical view

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We have performed an optical spectroscopic and photometric search for young stellar objects associated with the molecular cloud Lynds 1340, and examined the structure of the cloud by constructing an extinction map, based on *SDSS* data. The new extinction map suggests a shallow, strongly fragmented cloud, having a mass of some 3700 $M_\odot$. Longslit spectroscopic observations of the brightest stars over the area of L1340 revealed that the most massive star associated with L1340 is a B4 type, ~ 5 $M_\odot$ star. The new spectroscopic and photometric data of the intermediate mass members led to a revised distance of 825^{+110}_{-80} pc, and revealed seven members of the young stellar population with M $\gtrsim$2 $M_\odot$. Our search for Hα emission line stars, conducted with the *Wide Field Grism Spectrograph* 2 on the 2.2-meter telescope of the University of Hawaii and covering a $30' \times 40'$ area, resulted in the detection of 75 candidate low-mass pre-main sequence stars, 58 of which are new. We constructed spectral energy distributions of our target stars, based on *SDSS*, *2MASS*, *Spitzer*, and *WISE* photometric data, derived their spectral types, extinctions, and luminosities from *BVRIJ* fluxes, estimated masses by means of pre-main sequence evolutionary models, and examined the disk properties utilizing the 2–24 μm interval of the spectral energy distribution. We measured the equivalent width of the Hα lines and derived accretion rates. The optically selected sample of pre-main sequence stars has a median effective temperature of 3970 K, stellar mass 0.7 $M_\odot$, and accretion rate of 7.6×10^{-9} $M_\odot$ yr^{-1}.

Accepted by ApJ

http://arxiv.org/pdf/1602.08120.pdf

The young stellar population of Lynds 1340. An infrared view

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We present results of an infrared study of the molecular cloud Lynds 1340, forming three groups of low and intermediate-mass stars. Our goals are to identify and characterise the young stellar population of the cloud, study the relationships between the properties of the cloud and the emergent stellar groups, and integrate L1340 into the picture of the star-forming activity of our Galactic environment. We selected candidate young stellar objects from the *Spitzer* and *WISE* data bases using various published color criteria, and classified them based on the slope of the spectral energy distribution. We identified 170 *Class II*, 27 *Flat SED*, and 45 *Class 0/I* sources. High angular resolution near-infrared observations of the RNO 7 cluster, embedded in L1340, revealed eight new young stars of near-infrared excess. The surface density distribution of young stellar objects shows three groups, associated with the three major molecular clumps of L1340, each consisting of $\lesssim$100 members, including both pre-main sequence stars and embedded protostars. New Herbig–Haro objects were identified in the *Spitzer* images. Our results demonstrate that L1340 is a prolific star-forming region of our Galactic environment in which several specific properties of the intermediate-mass mode of star formation can be studied in detail.

Accepted by ApJS

http://arxiv.org/pdf/1602.08053.pdf

The orbit of β Pic b as a transiting planet

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In 1981, β Pictoris showed strong and rapid photometric variations possibly due to a transiting giant planet. Later, a planetary mass companion to the star, β Pic b, was identified using imagery. Observations at different epochs (2003 and 2009–2015) detected the planet at a projected distance of 6 to 9 AU from the star and showed that the planet is on an edge-on orbit. The observed motion is consistent with an inferior conjunction in 1981, and β Pic b can be the transiting planet proposed to explain the photometric event observed at that time. Assuming that the 1981 event is related to the transit or the inferior conjunction of β Pic b on an edge-on orbit, we search for the planetary orbit in agreement with all the measurements of the planet position published so far. We find two different orbits that are compatible with all these constraints: (i) an orbit with a period of 17.97$\pm$0.08 years along with an eccentricity of around 0.12 and (ii) an orbit with a period of 36.38$\pm$0.13 years and a larger eccentricity of about 0.32. In the near future, new imaging observations should allow us to discriminate between these two different orbits. We also estimate

the possible dates for the next transits, which could take place as early as 2017 or 2018, even for a long-period orbit.

Accepted by A&A

http://arxiv.org/pdf/1602.04683

Circumstellar Disks of the Most Vigorously Accreting Young Stars

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Young stellar objects (YSOs) may not accumulate their mass steadily, as was previously thought, but in a series of violent events manifesting themselves as sharp stellar brightening. These events can be caused by fragmentation due to gravitational instabilities in massive gaseous disks surrounding young stars, followed by migration of dense gaseous clumps onto the star. We report our high angular resolution, coronagraphic near-infrared polarization imaging observations using the High Contrast Instrument for the Subaru Next Generation Adaptive Optics (HiCIAO) of the Subaru 8.2 m Telescope, towards four YSOs which are undergoing luminous accretion outbursts.The obtained infrared images have verified the presence of several hundred AUs scale arms and arcs surrounding these YSOs. In addition, our hydrodynamics simulations and radiative transfer models further demonstrate that these observed structures can indeed be explained by strong gravitational instabilities occurring at the beginning of the disk formation phase. The effect of those tempestuous episodes of disk evolution on star and planet formation remains to be understood.

Accepted by Science Advances

http://advances.sciencemag.org/content/2/2/e1500875
http://arxiv.org/pdf/1602.04068

Detection of Linearly Polarized 6.9 mm Continuum Emission from the Class 0 Young Stellar Object NGC1333 IRAS4A

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We report new Karl G. Jansky Very Large Array (JVLA), 0."5 angular resolution observations of linearly polarized continuum emission at 6.9 mm, towards the Class 0 young stellar object (YSO) NGC1333 IRAS4A. This target

source is a collapsing dense molecular core, which was resolved at short wavelengths to have hourglass shaped B-field configuration. We compare these 6.9 mm observations with previous polarization Submillimeter Array (SMA) observations at 0.88 mm, which have comparable angular resolution ($\sim 0''.7$). We found that at the same resolution, the observed polarization position angles at 6.9 mm are slightly deviated from those observed at 0.88 mm. Due to the lower optical depth of the emission at 6.9 mm, and the potential effect of dust grain growth, the new JVLA observations are likely probing B-field alignments in regions interior to those sampled by the previous polarization observations at higher frequencies. Our understanding can be improved by more sensitive observations, and observations for the more extended spatial scales.

Accepted by ApJ

http://adsabs.harvard.edu/pdf/2016arXiv160204077L

Forming isolated brown dwarfs by turbulent fragmentation

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We use Smoothed Particle Hydrodynamics to explore the circumstances under which an isolated very-low-mass prestellar core can be formed by colliding turbulent flows and collapse to form a brown-dwarf. Our simulations suggest that the flows need not be very fast, but do need to be very strongly convergent, i.e. the gas must flow in at comparable speeds *from all sides*, which seems rather unlikely. We therefore revisit the object Oph-B11, which AWG12 have identified as a prestellar core with mass between $\sim 0.020\,\mathrm{M}_{\odot}$ and $\sim 0.030\,\mathrm{M}_{\odot}$. We reanalyse the observations using a Markov-chain Monte Carlo method that allows us (i) to include the uncertainties on the distance, temperature and dust mass opacity, and (ii) to consider different Bayesian prior distributions of the mass. We estimate that the posterior probability that Oph-B11 has a mass below the hydrogen burning limit at $\sim 0.075\,\mathrm{M}_{\odot}$, is between 0.66 and 0.86 . We conclude that, if Oph-B11 is destined to collapse, it probably will form a brown dwarf. However, the flows required to trigger this appear to be so contrived that it is difficult to envisage this being the only way, or even a major way, of forming isolated brown dwarfs. Moreover, Oph-B11 could easily be a transient, bouncing, prolate core, seen end-on; there could, indeed should, be many such objects masquerading as very low-mass prestellar cores.

Accepted by MNRAS

http://arxiv.org/pdf/1602.05789

Young and embedded clusters in Cygnus-X: evidence for building up the IMF?

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We provide a new view on the Cygnus-X north complex by accessing for the first time the low mass content of young stellar populations in the region. CFHT/WIRCam camera was used to perform a deep near-IR survey of this complex, sampling stellar masses down to $\sim$0.1 $M_{\odot}$. Several analysis tools, including a extinction treatment developed in this work, were employed to identify and uniformly characterise a dozen unstudied young star clusters in the area. Investigation of their mass distributions in low-mass domain revealed a relatively uniform log-normal IMF with a characteristic mass of 0.32$\pm$0.08 $M_{\odot}$ and mass dispersion of 0.40$\pm$0.06. In the high mass regime, their derived slopes showed that while the youngest clusters (age $<$ 4 Myr) presented slightly shallower values with respect to the Salpeter's, our older clusters (4 Myr $<$ age $<$ 18 Myr) showed IMF compliant values and a slightly denser stellar population. Although possibly evidencing a deviation from an 'universal' IMF, these results also supports a scenario where these gas dominated young clusters gradually 'build up' their IMF by accreting low-mass stars formed in their vicinity during their first $\sim$3 Myr, before the gas expulsion phase, emerging at the age of $\sim$4 Myr with a fully fledged

IMF. Finally, the derived distances to these clusters confirmed the existence of at least 3 different star forming regions throughout Cygnus-X north complex, at distances of 500–900 pc, 1.4–1.7 kpc and 3.0 kpc, and revealed evidence of a possible interaction between some of these stellar populations and the Cygnus-OB2 association.

Accepted by MNRAS

http://arxiv.org/pdf/1602.07341

Detection of CH_3SH in protostar IRAS 16293−2422

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The nature of the main sulphur reservoir in star forming regions is a long standing mystery. The observed abundance of sulphur-bearing species in dense clouds is only about 0.1 per cent of the same quantity in diffuse clouds. Therefore, the main sulphur species in star forming regions of the interstellar medium are still unknown. IRAS 16293−2422 is one of the regions where production of S-bearing species is favourable due to its conditions which allows the evaporation of ice mantles. We carried out observations in the 3 mm band towards the solar type protostar IRAS 16293−2422 with the IRAM 30m telescope. We observed a single frequency setup with the EMIR heterodyne 3 mm receiver with an Lower Inner (LI) tuning frequency of 89.98 GHz. Several lines of the complex sulphur species CH_3SH were detected. Observed abundances are compared with simulations using the NAUTILUS gas-grain chemical model. Modelling results suggest that CH_3SH has the constant abundance of 4×10^{-9} (compared to H_2) for radii lower than 200 AU and is mostly formed on the surfaces. Detection of CH_3SH indicates that there may be several new families of S-bearing molecules (which could form starting from CH_3SH) which have not been detected or looked for yet.

Accepted by MNRAS

http://arxiv.org/pdf/1602.07619

Far-infrared/sub-millimetre properties of pre-stellar cores L1521E, L1521F and L1689B as revealed by the Herschel SPIRE instrument – I. Central positions

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Dust grains play a key role in the physics of star-forming regions, even though they constitute only ∼1 % of the mass of the interstellar medium. The derivation of accurate dust parameters such as temperature ($T_{\rm d}$), emissivity spectral index (β) and column density requires broadband continuum observations at far-infrared wavelengths. We present *Herschel*-SPIRE Fourier Transform Spectrometer (FTS) measurements of three starless cores: L1521E, L1521F and L1689B, covering wavelengths between 194 and 671 μm. This paper is the first to use our recently updated SPIRE-FTS intensity calibration, yielding a direct match with SPIRE photometer measurements of extended sources. In addition, we carefully assess the validity of calibration schemes depending on source extent and on the strength of background emission. The broadband far-infrared spectra for all three sources peak near 250 μm. Our observations therefore provide much tighter constraints on the spectral energy distribution (SED) shape than measurements that do not probe the SED peak. The spectra are fitted using modified blackbody functions, allowing both T_d and β to vary as free parameters. This yields T_d of 9.8±0.2 K, 15.6±0.5 K and 10.9±0.2 K and corresponding β of 2.6∓0.9, 0.8∓0.1 and 2.4∓0.8 for L1521E, L1521F and L1689B respectively. The derived core masses are 1.0±0.1, 0.10±0.01 and 0.49±0.05 $M_\odot$, respectively. The core mass/Jeans mass ratios for L1521E and L1689B exceed unity indicating that they are unstable to gravitational collapse, and thus pre-stellar cores. By comparison, the elevated temperature and gravitational stability of L1521F support previous arguments that this source is more evolved and likely a protostar.

Accepted by MNRAS

http://arxiv.org/pdf/1602.06927

A census of dense cores in the Taurus L1495 cloud from the Herschel Gould Belt Survey

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We present a catalogue of dense cores in a $\sim 4^\circ \times 2^\circ$ field of the Taurus star-forming region, inclusive of the L1495 cloud, derived from *Herschel* SPIRE and PACS observations in the 70 μm, 160 μm, 250 μm, 350 μm, and 500 μm continuum bands. Estimates of mean dust temperature and total mass are derived using modified blackbody fits to the spectral energy distributions. We detect 525 starless cores of which $\sim$ 10–20% are gravitationally bound and therefore presumably prestellar. Our census of unbound objects is $\sim$ 85% complete for $M > 0.015\,M_\odot$ in low density regions ($A_V \lesssim 5$ mag), while the bound (prestellar) subset is $\sim$ 85% complete for $M > 0.1\,M_\odot$ overall. The prestellar core mass function (CMF) is consistent with lognormal form, resembling the stellar system initial mass function, as has been reported previously. All of the inferred prestellar cores lie on filamentary structures whose column densities exceed the expected threshold for filamentary collapse, in agreement with previous reports. Unlike the prestellar CMF, the unbound starless CMF is not lognormal, but instead is consistent with a power-law form below $0.3\,M_\odot$ and shows no evidence for a low-mass turnover. It resembles previously reported mass distributions for CO clumps at low masses ($M \lesssim 0.3\,M_\odot$). The volume density PDF, however, is accurately lognormal except at high densities. It is consistent with the effects of self-gravity on magnetised supersonic turbulence. The only significant deviation from log normality is a high-density tail which can be attributed unambiguously to prestellar cores.

Accepted by MNRAS

http://arxiv.org/pdf/1602.03143

The effect of ambipolar diffusion on low-density molecular ISM filaments

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The filamentary structure of the molecular interstellar medium and the potential link of this morphology to star formation have been brought into focus recently by high resolution observational surveys. An especially puzzling matter is that local interstellar filaments appear to have the same thickness, independent of their column density. This requires a theoretical understanding of their formation process and the physics that governs their evolution. In this work we explore a scenario in which filaments are dissipative structures of the large-scale interstellar turbulence cascade and ion-neutral friction (also called ambipolar diffusion) is affecting their sizes by preventing small-scale compressions. We employ high-resolution, 3D MHD simulations, performed with the grid code RAMSES, to investigate non-ideal MHD turbulence as a filament formation mechanism. We focus the analysis on the mass and thickness distributions of the resulting filamentary structures. Simulations of both driven and decaying MHD turbulence show that the morphologies of the density and the magnetic field are different when ambipolar diffusion is included in the models. In particular, the densest structures are broader and more massive as an effect of ion-neutral friction and the power spectra of both the velocity and the density steepen at a smaller wavenumber. The comparison between ideal and non-ideal MHD simulations shows that ambipolar diffusion causes a shift of the filament thickness distribution towards higher values. However, none of the distributions exhibit the pronounced peak found in the observed local filaments. Limitations in dynamical range and the absence of self-gravity in these numerical experiments do not allow us to conclude at this time whether this is due to the different filament selection or due to the physics inherent of the filament formation.

Accepted by A&A

http://arxiv.org/pdf/1602.04737

Supernova Driving. I. The Origin of Molecular Cloud Turbulence

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Turbulence is ubiquitous in molecular clouds (MCs), but its origin is still unclear because MCs are usually assumed to live longer than the turbulence dissipation time. Interstellar medium (ISM) turbulence is likely driven by SN explosions, but it has never been demonstrated that SN explosions can establish and maintain a turbulent cascade inside MCs consistent with the observations. In this work, we carry out a simulation of SN-driven turbulence in a volume of $(250\ \mathrm{pc})^3$, specifically designed to test if SN driving alone can be responsible for the observed turbulence inside MCs. We find that SN driving establishes a velocity scaling consistent with the usual scaling laws of supersonic turbulence, suggesting that previous idealized simulations of MC turbulence, driven with a random, large-scale volume force, were correctly adopted as appropriate models for MC turbulence, despite the artificial driving. We also find that the same scaling laws extend to the interior of MCs, and that the velocity-size relation of the MCs selected from our simulation is consistent with that of MCs from the Outer-Galaxy Survey, the largest MC sample available. The mass-size relation and the mass and size probability distributions also compare successfully with those of the Outer Galaxy Survey. Finally, we show that MC turbulence is super-Alfvénic with respect to both the mean and rms magnetic-field strength. We conclude that MC structure and dynamics are the natural result of SN-driven turbulence.

Accepted by Astrophysical Journal

http://arxiv.org/pdf/1509.04663

Protostars: forge of cosmic rays?

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Galactic cosmic rays are particles presumably accelerated in supernova remnant shocks that propagate in the interstellar medium up to the densest parts of molecular clouds, losing energy as well as their ionisation efficiency because of the presence of magnetic fields and collisions with molecular hydrogen. Recent observations hint at high levels of ionisation and to the presence of synchrotron emission in protostellar systems, therefore leading to an apparent contradiction. We want to explain the origin of these cosmic rays accelerated within young protostars as suggested by observations. Our modelling consists of a set of conditions that has to be satisfied in order to have an efficient cosmic-ray acceleration through diffusive shock acceleration. We analyse three main acceleration sites (shocks in accretion flows, along the jets, and on protostellar surfaces), then we follow the propagation of these particles through the protostellar system up to the hot spot region. We find that jet shocks can be strong accelerators of cosmic-ray protons, which can be boosted up to relativistic energies. Another promising acceleration site is protostellar surfaces, where shocks caused by impacting material during the collapse phase are strong enough to accelerate cosmic-ray protons. In contrast, accretion flow shocks are too weak to efficiently accelerate cosmic rays. Though cosmic-ray electrons are weakly accelerated, they can gain a strong boost to relativistic energies through re-acceleration in successive shocks. We suggest a mechanism able to accelerate both cosmic-ray protons and electrons through the diffusive shock acceleration, which can be used to explain the high ionisation rate as well as the synchrotron emission observed towards protostellar sources. The existence of an internal source of energetic particles can have a strong and unforeseen impact on the ionisation of the protostellar disc, on the star and planet formation process as well as on the formation of pre-biotic molecules.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/1602.08495

The complex high-mass star-forming region IRAS 15507-5359

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The far-infrared IRAS15507-5359 source is known to be a medium-mass star- forming region associated with a compact HII region and a near-infrared embedded cluster. We present a survey of infrared-calibrated images ranging from 1.2 to 500 μm obtained with the Baade telescope at Las Campanas Observatory, and the Herschel space telescope with additional archive Spitzer data. We confirm the distance to the complex to be 5.0 kpc. Three Herschel far-infrared sources are found, I, II, III, identified with dense cores at different evolutionary stages. One (III) is a starless infrared dark cloud showing, near its edge, two infrared reflection nebulae (R1) and (R2) with dispersed young stellar populations, including a knot of shocked H_2-line emission. Both show considerable polycyclic aromatic hydrocarbon emission. Core II has associated a radio HII region and a deeply embedded one-million-year-old cluster (Cl 1) that contains more than 45 young stellar objects, reddened by at least 20 visual magnitudes. About 20% of them show considerable infrared excess emission. Core I appears void of a near-infrared population, and coincides with a long emission bar that resembles a photodissociation front. We determine the properties of the two most luminous Class I sources in the region by fitting models of young stars with accreting discs and envelopes to their 1 to 500 μm spectral energy distributions. This is another example of a medium-mass region with at least three well-defined active centres of star formation separated by about 1 pc and at different evolutionary stages.

Accepted by MNRAS

ftp.astrosen.unam.mx/iauname/mt/paolo/

The time evolution of HH 1 from four epochs of HST images

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We present an analysis of four epochs of Hα and [S II] $\lambda\lambda$ 6716/6731 HST images of HH 1. For determining proper motions we explore a new method based on analysis of spatially degraded images obtained convolving the images with wavelet functions of chosen widths. With this procedure we are able to generate maps of proper motion velocities along and across the outflow axis, as well as (angularly integrated) proper motion velocity distributions. From the four available epochs, we find the time evolution of the velocities, intensities and spatial distribution of the line emission. We find that over the last two decades HH 1 shows a clear acceleration. Also, the Hα and [S II] intensities have first dropped, and then recovered in the more recent (2014) images. Finally, we show a comparison between the two available HST epochs of [O III] λ 5007 (1994 and 2014), in which we see a clear drop in the value of the [O III]/Hα ratio.

Accepted by Astron. J.

https://arxiv.org/pdf/1603.01572
http://bigbang.nucleares.unam.mx/astroplasmas/

Did Jupiter's core form in the innermost parts of the Sun's protoplanetary disk?

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Jupiter's core is generally assumed to have formed beyond the snow line. Here we consider an alternative scenario, that Jupiter's core may have accumulated in the innermost parts of the protoplanetary disk. A growing body of research suggests that small particles ("pebbles") continually drift inward through the disk. If a fraction of drifting pebbles is trapped at the inner edge of the disk a several Earth-mass core can quickly grow. Subsequently, the core may migrate outward beyond the snow line via planet-disk interactions. Of course, to reach the outer Solar System Jupiter's core must traverse the terrestrial planet-forming region.

We use N-body simulations including synthetic forces from an underlying gaseous disk to study how the outward migration of Jupiter's core sculpts the terrestrial zone. If the outward migration is fast ($T_{\rm mig} \sim 10^4$ years), the core simply migrates past resident planetesimals and planetary embryos. However, if its migration is slower ($T_{\rm mig} \sim 10^5$ years) the core removes solids from the inner disk by shepherding objects in mean motion resonances. In many cases the disk interior to 0.5–1 AU is cleared of embryos and most planetesimals. By generating a mass deficit close to the Sun, the outward migration of Jupiter's core may thus explain the absence of terrestrial planets closer than Mercury. Jupiter's migrating core often stimulates the growth of another large (∼Earth-mass) core — that may provide a seed for Saturn's core — trapped in exterior resonance. The migrating core also may transport a fraction of terrestrial planetesimals, such as the putative parent bodies of iron meteorites, to the asteroid belt.

Accepted by MNRAS

http://arxiv.org/pdf/1602.06573

Constraining the properties of transitional disks in Chamaeleon I with Herschel

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Transitional disks are protoplanetary disks with opacity gaps/cavities in their dust distribution, a feature that may be linked to planet formation. We perform Bayesian modeling of the three transitional disks SZ Cha, CS Cha and T25 including photometry from the *Herschel Space Observatory* to quantify the improvements added by these new data. We find disk dust masses between $2{\times}10^{-5}$ and $4{\times}10^{-4}\,M_\odot$ and gap radii in the range of 7-18 AU, with uncertainties of $\sim$one order of magnitude and $\sim$4 AU, respectively. Our results show that adding *Herschel* data can significantly improve these estimates with respect to mid-infrared data alone, which have roughly twice as large uncertainties on both disk mass and gap radius. We also find weak evidence for different density profiles with respect to full disks. These results open exciting new possibilities to study the distribution of disk masses for large samples of disks.

Accepted by MNRAS

http://arxiv.org/pdf/1602.03183v1.pdf

A Uniform Catalog of Molecular Clouds in the Milky Way

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The all-Galaxy CO survey of Dame, Hartmann, & Thaddeus (2001) is by far the most uniform, large-scale Galactic CO survey. Using a dendrogram-based decomposition of this survey, we present a catalog of 1064 massive molecular clouds throughout the Galactic plane. This catalog contains $2.5 \times 10^8\ M_\odot$, or $25^{+10.7}_{-5.8}\%$ of the Milky Way's estimated H_2 mass. We track clouds in some spiral arms through multiple quadrants. The power index of Larson's first law, the size-linewidth relation, is consistent with 0.5 in all regions — possibly due to an observational bias — but clouds in the inner Galaxy systematically have significantly (∼30%) higher linewidths at a given size, indicating that their linewidths are set in part by Galactic environment. The mass functions of clouds in the inner Galaxy versus the outer Galaxy are both qualitatively and quantitatively distinct. The inner Galaxy mass spectrum is best described by a truncated power-law with a power index of $\gamma = -1.6 \pm 0.1$ and an upper truncation mass $M_0 = (1.0 \pm 0.2) \times 10^7\ M_\odot$, while the outer Galaxy mass spectrum is better described by a non-truncating power law with $\gamma = -2.2 \pm 0.1$ and an upper mass $M_0 = (1.5 \pm 0.5) \times 10^6\ M_\odot$, indicating that the inner Galaxy is able to form and host substantially more massive GMCs than the outer Galaxy. Additionally, we have simulated how the Milky Way would appear in CO from extragalactic perspectives, for comparison with CO maps of other galaxies.

Accepted by ApJ

http://arxiv.org/pdf/1602.02791

Understanding discs in binary YSOs: detailed modelling of VV CrA

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Given that a majority of stars form in multiple systems, in order to fully understand the star- and planet-formation processes we must seek to understand them in multiple stellar systems. With this in mind, we present an analysis of the enigmatic binary T-Tauri system VV Corona Australis, in which both components host discs, but only one is visible at optical wavelengths. We seek to understand the peculiarities of this system by searching for a model for the binary which explains all the available continuum observations of the system. We present new mid-infrared interferometry and near-infrared spectroscopy along with archival millimetre-wave observations, which resolve the binary at 1.3mm for the first time. We compute a grid of pre-main-sequence radiative transfer models and calculate their posterior probabilities given the observed spectral energy distributions and mid-infrared interferometric visibilities of the binary components, beginning with the assumption that the only differences between the two components are their inclination and position angles. Our best-fitting solution corresponds to a relatively low luminosity T-tauri binary, with each component's disc having a large scale height and viewed at moderate inclination ($\sim 50°$), with the infrared companion inclined by $5°$ more than the primary. Comparing the results of our model to evolutionary models suggests stellar masses $\sim 1.7\ M_{\odot}$ and an age for the system of 3.5 Myr, towards the upper end of previous estimates. Combining these results with accretion indicators from near-IR spectroscopy, we determine an accretion rate of $4.0 \times 10^{-8}\ M_{\odot}\ \mathrm{yr}^{-1}$ for the primary. We suggest that future observations of VV CrA and similar systems should prioritise high angular resolution sub-mm and near-IR imaging of the discs and high resolution optical/NIR spectroscopy of the central stars.

Accepted by MNRAS

http://arxiv.org/pdf/1602.07380

Structural studies of eight bright rimmed clouds in the southern hemisphere

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We carried out deep and wide-field near- and mid-infrared observations for a sample of 8 bright-rimmed clouds (BRCs). Supplemented with the *Spitzer* archival data, we have identified and classified 44 to 433 young stellar objects (YSOs) associated with these BRCs. The Class I sources are generally located towards the places with higher extinction and are relatively closer to each other than the Class II sources, confirming that the young protostars are usually found in regions having denser molecular material. On the other hand the comparatively older population, Class II objects,

are more randomly found throughout the regions, which can be due to their dynamical evolution. Using the minimal sampling tree analyses, we have extracted 13 stellar cores of 8 or more members, which contains 60% of the total YSOs. The typical core is ∼0.6 pc in radii and somewhat elongated (aspect ratio of 1.45), of relatively low stellar density (surface density 60 pc^{-2}), consisting of a small (35) number of YSOs of relatively young sources (66% Class I), and partially embedded (median A_K =1.1 mag). But the cores show a wide range in their mass distribution (∼20 to 2400 $M_\odot$) with a median value of around 130 $M_\odot$. We have found the star formation efficiencies in the cores to be between 3% and 30% with an average of ∼14%, which agree with the efficiencies needed to link the core mass function to the initial mass function. We also found a linear relation between the density of the clouds and the number of YSOs. The peaked nearest neighbor spacing distributions of the YSOs and the ratio of Jeans lengths to the YSOs separations indicates a significant degree of non-thermally driven fragmentation in these BRCs.

Accepted by The Astronomical Journal

http://arxiv.org/pdf/1602.07798

Stable and Unstable Regimes of Mass Accretion onto RW Aur A

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We present monitoring observations of the active T Tauri star RW Aur, from 2010 October to 2015 January, using optical high-resolution ($R \geq 10000$) spectroscopy with CFHT-ESPaDOnS. Optical photometry in the literature shows bright, stable fluxes over most of this period, with lower fluxes (by 2-3 mag.) in 2010 and 2014. In the bright period our spectra show clear photospheric absorption, complicated variation in the Ca II 8542 Å emission profile shapes, and a large variation in redshifted absorption in the O I 7772 and 8446 Å and He I 5876 Å lines, suggesting unstable mass accretion during this period. In contrast, these line profiles are relatively uniform during the faint periods, suggesting stable mass accretion. During the faint periods the photospheric absorption lines are absent or marginal, and the averaged Li I profile shows redshifted absorption due to an inflow. We discuss (1) occultation by circumstellar material or a companion and (2) changes in the activity of mass accretion to explain the above results, together with near-infrared and X-ray observations from 2011-2015. Neither scenario can simply explain all the observed trends, and more theoretical work is needed to further investigate their feasibilities.

Accepted by Astrophysical Journal

http://arxiv.org/pdf/1602.07372

An Ordered Bipolar Outflow from a Massive Early-Stage Core

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We present *ALMA* follow-up observations of two massive, early-stage core candidates, C1-N & C1-S, in Infrared Dark Cloud (IRDC) G028.37+00.07, which were previously identified by their N_2D^+(3-2) emission and show high levels of deuteration of this species. The cores are also dark at far infrared wavelengths up to $\sim 100\,\mu$m. We detect ^{12}CO(2-1) from a narrow, highly-collimated bipolar outflow that is being launched from near the center of the C1-S core, which is also the location of the peak 1.3 mm dust continuum emission. This protostar, C1-Sa, has associated dense gas traced by $C^{18}O$(2-1) and DCN(3-2), from which we estimate it has a radial velocity that is near the center of the range exhibited by the C1-S massive core. A second outflow-driving source is also detected within the projected boundary of C1-S, but appears to be at a different radial velocity. After considering properties of the outflows, we conclude C1-Sa is a promising candidate for an early-stage massive protostar and as such it shows that these early phases of massive star formation can involve highly ordered outflow, and thus accretion, processes, similar to models developed to explain low-mass protostars.

Accepted by Astrophysical Journal Letters

http://arxiv.org/pdf/1601.07043

Formation and recondensation of complex organic molecules during protostellar luminosity outbursts

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During the formation of stars, the accretion of the surrounding material toward the central object is thought to undergo strong luminosity outbursts, followed by long periods of relative quiescence, even at the early stages of star formation when the protostar is still embedded in a large envelope. We investigated the gas phase formation and the recondensation of the complex organic molecules (COMs) di-methyl ether and methyl formate, induced by sudden ice evaporation processes occurring during luminosity outbursts of different amplitudes in protostellar envelopes. For this purpose, we updated a gas phase chemical network forming complex organic molecules in which ammonia plays a key role. The model calculations presented here demonstrate that ion-molecule reactions alone could account for the observed presence of di-methyl ether and methyl formate in a large fraction of protostellar cores, without recourse to grain-surface chemistry, although they depend on uncertain ice abundances and gas phase reaction branching ratios. In spite of the short outburst timescales of about one hundred years, abundance ratios of the considered species with respect to methanol higher than 10% are predicted during outbursts due to their low binding energies relative to water and methanol that delay their recondensation during the cooling. Although the current luminosity of most embedded protostars would be too low to produce these complex species in hot core regions that can be observable with current sub-millimetric interferometers, previous luminosity outburst events would induce a formation of COMs in extended regions of protostellar envelopes with sizes increasing by up to one order of magnitude.

Accepted by ApJ

http://arxiv.org/pdf/1602.05364

Chemistry as a diagnostic of prestellar core geometry

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We present a new method for assessing the intrinsic 3D shape of prestellar cores from molecular column densities. We have employed hydrodynamic simulations of contracting, isothermal cores considering three intrinsic geometries: spherical, cylindrical/filamentary and disk-like. We have coupled our hydrodynamic simulations with non-equilibrium chemistry. We find that a) when cores are observed very elongated (i.e. for aspect ratios $\leq$0.15) the intrinsic 3D geometry can be probed by their 2D molecular emission maps, since these exhibit significant qualitative morphological differences between cylindrical and disk-like cores. Specifically, if a disk-like core is observed as a filamentary object in dust emission, then it will be observed as two parallel filaments in N_2H^+; b) for cores with higher aspect ratios (i.e. 0.15–0.9) we define a metric Δ that quantifies whether a molecular column density profile is centrally peaked, depressed or flat. We have identified one molecule (CN) for which Δ as a function of the aspect ratio probes the 3D geometry of the core; and c) for cores with almost circular projections (i.e. for aspect ratios $\sim$1), we have identified three molecules (OH, CO and H_2CO) that can be used to probe the intrinsic 3D shape by close inspection of their molecular column density radial profiles. We alter the temperature and the cosmic-ray ionization rate and demonstrate that our method is robust against the choice of parameters.

Accepted by MNRAS

http://arxiv.org/pdf/1602.03187

Magnetic field and early evolution of circumstellar disks

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The magnetic field plays a central role in the formation and evolution of circumstellar disks. The magnetic field connects the rapidly rotating central region with the outer envelope and extracts angular momentum from the central region during gravitational collapse of the cloud core. This process is known as magnetic braking. Both analytical and multidimensional simulations have shown that disk formation is strongly suppressed by magnetic braking in moderately magnetized cloud cores in the ideal magnetohydrodynamic limit. On the other hand, recent observations have provided growing evidence of a relatively large disk several tens of astronomical units in size existing in some Class 0 young stellar objects. This introduces a serious discrepancy between the theoretical study and observations. Various physical mechanisms have been proposed to solve the problem of catastrophic magnetic braking, such as misalignment between the magnetic field and the rotation axis, turbulence, and non-ideal effect. In this paper, we review the mechanism of magnetic braking, its effect on disk formation and early evolution, and the mechanisms that resolve the magnetic braking problem. In particular, we emphasize the importance of non-ideal effects. The combination of magnetic diffusion and thermal evolution during gravitational collapse provides a robust formation process for the circumstellar disk at the very early phase of protostar formation. The rotation induced by the Hall effect can supply a sufficient amount of angular momentum for typical circumstellar disks around T Tauri stars. By examining the combination of the suggested mechanisms, we conclude that the circumstellar disks commonly form in the very early phase of protostar formation.

Accepted by PASA

http://arxiv.org/pdf/1602.04538

Comparing Young Massive Clusters and their Progenitor Clouds in the Milky Way

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Young massive clusters (YMCs) have central stellar mass surface densities exceeding 10^4 $M_\odot pc^{-2}$. It is currently unknown whether the stars formed at such high (proto)stellar densities. We compile a sample of gas clouds in the Galaxy which have sufficient gas mass within a radius of a few parsecs to form a YMC, and compare their radial gas mass distributions to the stellar mass distribution of Galactic YMCs. We find that the gas in the progenitor clouds is distributed differently than the stars in YMCs. The mass surface density profiles of the gas clouds are generally shallower than the stellar mass surface density profiles of the YMCs, which are characterised by prominent dense core regions with radii ~ 0.1 pc, followed by a power-law tail. On the scale of YMC core radii, we find that there are no known clouds with significantly more mass in their central regions when compared to Galactic YMCs. Additionally, we find that models in which stars form from very dense initial conditions require surface densities that are generally higher than those seen in the known candidate YMC progenitor clouds. Our results show that the quiescent, less evolved clouds contain less mass in their central regions than in the highly star-forming clouds. This suggests an evolutionary trend in which clouds continue to accumulate mass towards their centres after the onset of star formation. We conclude that a conveyor-belt scenario for YMC formation is consistent with the current sample of Galactic YMCs and their progenitor clouds.

Accepted by MNRAS

http://arxiv.org/pdf/1602.02762

The Massive Stellar Population of W49: A Spectroscopic Survey

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Massive stars form on different scales ranging from large, dispersed OB associations to compact, dense starburst clusters. The complex structure of regions of massive star formation, and the involved short timescales provide a challenge for our understanding of their birth and early evolution. As one of the most massive and luminous star-forming region in our Galaxy, W49 is the ideal place to study the formation of the most massive stars. By classifying the massive young stars deeply embedded into the molecular cloud of W49, we aim to investigate and trace the star formation history of this region. We analyse near-infrared K-band spectroscopic observations of W49 from LBT/LUCI combined with JHK images obtained with NTT/SOFI and LBT/LUCI. Based on JHK-band photometry and K-band spectroscopy the massive stars are placed in a Hertzsprung Russell diagram. By comparison with evolutionary models, their age and hence the star formation history of W49 can be investigated. Fourteen O type stars as well as two young stellar objects (YSOs) are identified by our spectroscopic survey. Eleven O-stars are main sequence stars with subtypes ranging from O3 to O9.5, with masses ranging from ~ 20 $M_\odot$ to ~ 120 $M_\odot$. Three of the O-stars show strong wind features, and are considered to be Of-type supergiants with masses beyond 100 $M_\odot$. The two YSOs show CO emission, indicative for the presence of circumstellar disks in the central region of the massive cluster. The age of the cluster is estimated as ~ 1.5 Myr, with star formation still ongoing in different parts of the region. The ionising photons from the central massive stars have not yet cleared the molecular cocoon surrounding the cluster. W49 is comparable to extragalactic star-forming regions and provides us with an unique possibility to study a starburst in detail.

Accepted by Astronomy and Astrophysics

http://arxiv.org/pdf/1602.05190v1.pdf

Gas Kinematics and Star Formation in the Filamentary IRDC G34.43+0.24

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We performed a multiwavelength study toward infrared dark cloud (IRDC) G34.43+0.24. New maps of ^{13}CO J=1–0 and C^{18}O J=1–0 were obtained from the Purple Mountain Observatory (PMO) 13.7 m radio telescope. At 8 μm (Spitzer - IRAC), IRDC G34.43+0.24 appears to be a dark filament extended by 18′ along the north-south direction. Based on the association with the 870 um and C^{18}O J=1–0 emission, we suggest that IRDC G34.43+0.24 should not be 18′ in length, but extend by 34′. IRDC G34.43+0.24 contains some massive protostars, UC H II regions, and infrared bubbles. The spatial extend of IRDC G34.43+0.24 is about 37 pc assuming a distance of 3.7 kpc. IRDC G34.43+0.24 has a linear mass density of 1.6×10^3 $M_\odot$ pc^{-1}, which is roughly consistent with its critical mass to length ratio. The turbulent motion may help stabilizing the filament against the radial collapse. Both infrared bubbles N61 and N62 show a ringlike structure at 8 um. Particularly, N61 has a double-shell structure, which has expanded into IRDC G34.43+0.24. The outer shell is traced by 8 μm and ^{13}CO J=1–0 emission, while the inner shell is traced by 24 μm and 20 cm emission. We suggest that the outer shell (9.9×10^5 yr) is created by the expansion of H II region G34.172+0.175, while the inner shell (4.1–6.3 $\times$ 10^5 yr) may be produced by the energetic stellar wind of its central massive star. From GLIMPSE I catalog, we selected some Class I sources with an age of 10^5 yr. These Class I sources are clustered along the filamentary molecular cloud.

Accepted by ApJ

http://arxiv.org/pdf/1602.06671

An OH(1720 MHz) Maser and a Nonthermal Radio Source in Sgr B2(M): A SNR–Molecular Cloud Interaction Site?

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Sgr B2 is a well-known star forming molecular cloud complex in the Galactic center region showing evidence of high energy activity as traced by the Kα neutral FeI line at 6.4 keV, as well as GeV and TeV γ-ray emission. Here we present VLA and GMRT observations with respective resolutions of $\approx 3.5'' \times 1.2''$ and $25'' \times 25''$ and report the detection of an OH(1720 MHz) maser, with no accompanying OH 1665, 1667 and 1612 MHz maser emission. The maser coincides with a 150 MHz nonthermal radio source in Sgr B2(M). This rare class of OH(1720 MHz) masers or the so-called supernova remnant (SNR) masers, with no main line transitions, trace shocked gas and signal the interaction of an expanding SNR with a molecular cloud. We interpret the 150 MHz radio source as either the site of a SNR – molecular gas interaction or a wind-wind collision in a massive binary system. The interaction of the molecular cloud and the nonthermal source enhances the cosmic-ray ionization rate, allows the diffusion of cosmic rays into the cloud and produces the variable 6.4 keV line, GeV and TeV γ-ray emission from Sgr B2(M). The cosmic ray electron interaction with the gas in the Galactic center can not only explain the measured high values of cosmic ray ionization and heating rates but also contribute to nonthermal bremsstrahlung continuum emission, all of which are consistent with observations.

Accepted by ApJL

http://arxiv.org/pdf/1603.00883

Studying the Outflow-Core Interaction with ALMA Cycle 1 Observations of the HH 46/47 Molecular Outflow

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We present ALMA Cycle 1 observations of the HH 46/47 molecular outflow using combined 12m array and 7m array observations. We use ^{13}CO and C^{18}O emission to correct for the ^{12}CO optical depth, to accurately estimate the outflow mass, momentum and kinetic energy. Applying the optical depth correction increases the mass estimate by a factor of 14, the momentum by a factor of 6, and the kinetic energy by a factor of about 2. The new ^{13}CO (1–0) and C^{18}O (1–0) data also allow us to trace denser and slower outflow material than that traced by ^{12}CO. These species are only detected within about 1–2 km s^{-1} from the cloud velocity. The cavity wall of the red lobe appears at very low velocities ($\sim$0.2 km s^{-1}). Combing the material traced only by ^{13}CO and C^{18}O, the measured total mass of the CO outflow is 1.4 $M_\odot$, the total momentum is 1.7 $M_\odot$ km s^{-1} and the total energy is 4.7×10^{43} erg, assuming $T_{\rm ex} = 15$ K. The improved angular resolution and sensitivity in ^{12}CO reveal more details of the outflow structure. Specifically, we find that the outflow cavity wall is composed of multiple shells entrained in a series of jet bow-shock events. The outflow kinetic energy distribution shows that even though the red lobe is mainly entrained by jet bow-shocks, more outflow energy is being deposited into the cloud at the base of the outflow cavity rather than around the heads of the bow shocks. The estimated outflow mass, momentum, and energy indicate that the outflow is capable to disperse the parent core within the typical lifetime of the embedded phase of a low-mass protostar, and regulating a core-to-star efficiency of 1/4–1/3. The ^{13}CO and C^{18}O emission also trace a circumstellar envelope with rotation and infall motions. In CS, we found possible evidence for a slowly-moving rotating outflow, which we believe is entrained not only poloidally but also toroidally by a wind launched from relatively large radii on the disk.

Accepted by ApJ

http://arxiv.org/pdf/1602.02388

Protostellar Disk Formation Enabled by Removal of Small Dust Grains

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It has been shown that a realistic level of magnetization of dense molecular cloud cores can suppress the formation of a rotationally supported disk (RSD) through catastrophic magnetic braking in the ideal MHD limit. In this study, we present conditions for the formation of RSDs through non-ideal MHD effects computed self-consistently from an equilibrium chemical network. We find that removing from the standard MRN distribution the large population of very small grains (VSGs) of $\sim$10 Å to few 100 Å that dominate the coupling of the bulk neutral matter to the magnetic field increases the ambipolar diffusivity by $\sim$1–2 orders of magnitude at densities below 10^{10} cm^{-3}. The enhanced ambipolar diffusion (AD) in the envelope reduces the amount of magnetic flux dragged by the collapse into the circumstellar disk-forming region. Therefore, magnetic braking is weakened and more angular momentum can

be retained. With continuous high angular momentum inflow, RSDs of tens of AU are able to form, survive, and even grow in size, depending on other parameters including cosmic-ray ionization rate, magnetic field strength, and rotation speed. Some disks become self-gravitating and evolve into rings in our 2D (axisymmetric) simulations, which have the potential to fragment into (close) multiple systems in 3D. We conclude that disk formation in magnetized cores is highly sensitive to chemistry, especially to grain sizes. A moderate grain coagulation/growth to remove the large population of VSGs, either in the prestellar phase or during free-fall collapse, can greatly promote AD and help formation of tens of AU RSDs.

Accepted by

http://arxiv.org/pdf/1602.02729

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Dissertation Abstracts

Molecular Outflows in Massive Star Forming Regions

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Ph.D dissertation directed by: Stuart Lumsden

Ph.D degree awarded: August 2015

This thesis presents millimetre continuum and molecular line observations exploring the properties of molecular outflows towards massive star forming regions. Massive stars produce some of the most energetic phenomena in the Galaxy, yet we still do not have a comprehensive understanding of how they actually form. Outflows are known to play a key role in this formation process and their properties, particularly how they change depending on the mass, luminosity and evolution of the driving source can shed light on how massive stars actually form. This thesis presents observations at both high (SMA 3 arcsec) and low (JCMT 15 arcsec) spatial resolution of the known jet/outflow tracers, SiO and ^{12}CO, towards a sample massive star forming region drawn from the RMS survey. Furthermore, the presence of infall signatures is explored through observations of HCO^+ and $H^{13}CO^+$, and the hot core nature of the regions is probed using tracers such as CH_3CN, HC_3N and CH_3OH.

SiO is detected towards ∼50% of the massive young stellar objects and Hii regions in the JCMT sample. The detection of SiO appears to be linked to the age of the RMS source, with the younger sources showing a stronger dependence with SiO. The presence of SiO also appears to be linked to the CO velocity, with SiO more efficiently tracing sources with higher velocity dispersions. In the MOPRA observations towards a sample of 33 RMS sources, CH_3CN is detected towards 66% of the sources, with the redder likely younger sources having the largest rotational temperatures.

This thesis presents the first interferometric SiO (5-4) and ^{12}CO (2-1) observations, taken with the SMA, towards the massive star forming region G203.3166/NGC 2264-C. In this intermediate/massive star forming cluster, SiO is again tracing the youngest sources. Both the SiO and ^{12}CO emission trace two bipolar, high velocity outflows towards the mm brightest, IR-dark, likely youngest sources in this region. In contrast the IR-bright RMS source, AFGL 989-IRS1, in NGC 2264-C displays no associated molecular outflow emission. Furthermore, the high resolution follow-up SMA observations towards G192.6005/S255IR and the first interferometric ^{12}CO and SiO observations towards G194.9349 show a high velocity outflow traced by ^{12}CO in each region. In both regions the outflow appears to be driven by the IR-bright RMS source. However, no high velocity SiO counterpart is observed in either region. Thus, the lack of associated SiO emission may be a sign of age in these regions.

http://etheses.whiterose.ac.uk/11180/2/thesis.pdf

New Jobs

Faculty Positions in Astrophysics at Instituto de Astrofisica de Atacama, Copiapo (Chile)

The Instituto de Astrofisica de Atacama (IAA) at the Universidad De Atacama (UDA) in Copiapo (Chile) invites applications for two faculty positions to join the IAA team.

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We are particularly interested in candidates with strong experience in one or more of these fields:

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-Extrasolar Planets;
-Formation, structure and evolution of stars;
-Milky Way: stellar populations, star clusters, variable stars, galactic structure;
-Terrestrial Mars analogs;
-Astrobiology.

The positions carry teaching duties in astronomy at the undergraduate level, with a load of 6h per week. The working language is English. While knowledge of Spanish is not required (teaching can be done in English), the successful candidates are expected to teach in Spanish within two years. The appointment at UDA will be for three years, with a first probation year, and the position is further extendable subject to performance.

Applicants should have a PhD in astronomy or physics or related sciences completed at least 3 years prior to the starting day of the contract.

To receive full consideration, applications must be sent by Friday 18 of March 2016, although the position will remain open until filled. Start date is expected to be October 2016.

Applications must be submitted by e-mail to Mauro Barbieri (mauro.barbieri@uda.cl), and they should include:
1) Cover letter,
2) Curriculum Vitae,
3) List of publications,
4) Statement of recent research achievements (max. 2 pages),
5) An outline of future research (min. 2 pages, max. 10 pages),
6) The contact details of three referees (one needs to be the last employer, the others needs to be aware of the recent work of the candidate).

Questions may be addressed to the previous e-mail address.

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http://www.vrip.uda.cl/frontend/noticia_completa/104

Postdoc Position in Theoretical/Computational Theory of Stellar Accretion and Winds

The astrophysics group at the University of Exeter invites applications for a postdoctoral research position, to work primarily with Dr. Sean Matt on theoretical studies of low-mass stars. The position is funded by a European Research Council grant (AWESoMeStars) and is initially for 3 years, with the possibility of extension, depending on progress and funding considerations.

A broad goal of the project is to understand the rotation and magnetic activity of sun-like and low-mass stars. To further this goal, the successful applicant will use multi-dimensional MHD simulations of young stars interacting with accretion disks. We are thus particularly interested in applicants with a strong background in computational and/or theoretical (magneto)hydrodynamics; prior work on star formation, accretion, outflows, or stellar rotation would be an additional asset. We will also consider exceptional candidates for other aspects of the project, in particular those with expertise suitable for (a) including coronal physics in global simulations of magnetic stellar winds, or (b) stellar evolution calculations that include rotation and comparing synthetic populations with large observational datasets.

Applicants must possess (or be near completion of) a relevant PhD. The position is available from July 2016, but start dates later in the year are acceptable. The starting salary will range from £25,769 on Grade E to £33,574 on Grade F, depending on qualifications and experience. Extensive supercomputing resources and substantial funding for computing equipment and travel will be available.

Please apply using the University's online application system (search for job reference `P51891` in the "keywords" field): `https://jobs.exeter.ac.uk`. Applications should include a CV and a brief research statement (2 pages max) describing past work and future interest. In addition, please have 3 letters of recommendation sent to `s.matt@exeter.ac.uk`, with the applicants name in the subject, before the deadline of April 1st.

New Directions in Planet Formation

Lorentz Center, Leiden, The Netherlands, 11-15 July 2016

In the past two decades over 2,000 exoplanets have been discovered with properties and orbital architectures very different from the solar system. Yet the theoretical foundations of planet formation theory still rely on a framework conceived for the solar system. This workshop will focus on new developments in dust coagulation, planetesimal formation, planetary growth and planetary migration. The goal of the workshop is to critically assess the viability of various theories on planet formation and establish new research directions.

The number of participants is limited to 55 and junior researchers in particular are encouraged to apply. We have around 30 free places in the workshop and 10 slots available for contributed talks (poster presentations are always possible). There is no registration fee.

Organisers: Ravit Helled (Tel Aviv University), Anders Johansen (Lund University) and Chris Ormel (University of Amsterdam)

Invited review speakers: Alessandro Morbidelli, Tristan Guillot, Shigeru Ida, Roman Rafikov, Willy Kley, Satoshi Okuzumi and Hal Levison.

Invited junior researchers: Joanna Drazkowska, Sebastiaan Krijt, Michiel Lambrechts, Katherine Kretke, Allona Vazan, Judith Szulagyi, Masahiro Ogihara and Beibei Liu.

Deadline for application: 31 March

Website: https://www.lorentzcenter.nl/lc/web/2016/799/info.php3?wsid=799\&venue=Oort

Contact: helled@post.tau.ac.il, anders@astro.lu.se, c.w.ormel@uva.nl

Star Formation 2016 at the University of Exeter

21-26 August 2016

We are happy to announce that registration is now open for Star Formation 2016.

We invite abstracts that span the full range of our field; over five days we will have sessions covering molecular clouds, protostellar cores, young stellar clusters, protostars, and planet-forming discs. Of course there will be plenty of time for social interaction including a barbeque, a conference dinner and various excursions, during which you can explore this beautiful part of England.

Full details of the conference organization, abstract submission, and payment and registration are given on the conference website (http://sf2016.co.uk).

Please note the following deadlines:

30th April 2016: Abstract submission deadline and end of early registration
17th June 2016: Registration closes

21st August 2016: Conference begins

The final programme for the conference will be announced in early June.

The standard cost for early registration including the conference fee and six nights accommodation is 600GBP (500GBP for postgraduate students).

We are looking forward to seeing you all in Exeter!

With best regards, Chris Brunt and Tim Harries, on behalf of the SOC

email: sf2016@astro.ex.ac.uk

web: http://sf2016.co.uk

facebook: http://www.facebook.com/groups/starformation2016

Scientific Organising Committee:

Philippe André, CEA-Saclay, France, Crystal Brogan, NRAO, USA, Chris Brunt (Co-Chair), University of Exeter, UK, Cathie Clarke, University of Cambridge, UK, Janet Drew, University of Hertfordshire, UK, Kees Dullemond, University of Heidelberg, Germany, Tim Harries (Co-Chair), University of Exeter, UK, Lynne Hillenbrand, Caltech, USA, Shu-ichiro Inutsuka, Nagoya University, Japan, John Monnier, University of Michigan, USA

Invited Speakers:

Richard Alexander, University of Leicester, UK, Catherine Espaillat, Boston University, USA, Anaelle Maury, CEA Saclay, France, Mike Meyer, ETH Zurich, Switzerland, Stella Offner, UMass Amherst, USA, Nicolas Peretto, University of Cardiff, UK, Kengo Tomida, University of Osaka, Japan, Stefanie Walch, University of Cologne, Germany

Star Formation In Different Environments
25 – 29 July, 2016
Quy Nhon, Viet Nam

Pre-conference bootcamp: 23-24 July, 2016

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

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

For any information on the conference or financial support, please contact sfde16@gmail.com

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

Star Clusters: from Infancy to Teenagehood. Max-Planck Haus, Heidelberg, Germany, 8 - 12 August 2016

Star cluster research is experiencing a very exciting decade. With the Atacama Large Millimeter / submillimeter Array and the Gaia astrometric satellite, we are now equipped to probe the full lifecycle of star clusters, from the properties of the molecular gas in which they form, to the properties of the stellar streams which dying clusters leave in their wake. To exploit fully and meaningfully these huge data flows, the active collaboration of observers and modellers is critically needed. What theoretical predictions are we able to make? What are the observable quantities? How well do we understand observational data?

Moreover, the time is ripe for a hard look at the physical conditions leading to the formation of clusters in the Galaxy and the Magellanic Clouds, and their imprint on the long term evolution of clusters. Our aim is therefore also to bring together experts working on the formation of the cluster gaseous precursors with those studying the latest stages of cluster dissolution.

Particular attention will be given to the first Gyr of cluster evolution, that is, the infancy and teenagehood of clusters. This is over that age range that most clusters in the Galactic disc dissolve and, therefore, the age range over which a good understanding of cluster mass-loss mechanisms is most critically needed. Moreover, this is by that cluster age that the intriguing multiple stellar populations of globular clusters have formed. A related question is thus whether their formation can be witnessed directly in massive clusters currently in their teenagehood, or whether a key role was played by the different environmental conditions at the time of their formation.

Conference website: http://wwwstaff.ari.uni-heidelberg.de/infant_clusters_2016/

Abstract submission deadline: April 3, 2016

SOC: Geneviève Parmentier (Heidelberg, co-Chair), Franca d'Antona (Roma, co-Chair), Christian Boily (Strasbourg), Thomas Henning (Heidelberg), Marco Lombardi (Milano), Tom Megeath (Toledo), Alison Sills (McMaster)

Heating and cooling processes in the ISM Cologne, Germany, 7.9. - 9.9. 2016

The objective of this workshop is to summarize our theoretical and observational understanding of the relative importance of the various heating and cooling processes in the ISM. Special emphasize will be given to understand heating via low- and high-velocity shocks and cooling through far-infrared (FIR) fine-structure lines of CII, OI, and NII, and rotational transitions of CO.

We want to discuss how to best combine observations using different instruments and settings on SOFIA and complementary telescopes to obtain a complete inventory of the main heating and cooling processes in individual regions. We address the Galactic and extra-galactic community as well as theoristst working in this field.

Session topics are:

- Session 1: Interpreting finestructure line observations
- Session 2: Heating and cooling processes
- Session 3: Accessing the THz (FIR) wavelength range
- Session 4: Radiative heating
- Session 5: Shocks

Webpage: https://www.astro.uni-koeln.de/hac2016

SOC: S. Bontemps (LAB, Bordeaux), C. Ferkinhoff (Winona State University, USA), J. Goicoechea (CSIC, Madrid), M. Kaufmann (San Jose University, USA), S. Madden (CEA, Saclay), N. Schneider (KOSMA), R. Shetty (ITA, Heidelberg), X. Tielens (Leiden Observatory), H. Zinnecker (DSI, Stuttgart)

The Dynamics of Star and Planet Formation
European Week of Astronomy and Space Science
6-8 July 2016

Recent results from Herschel, ALMA, and MUSE are revolutionising our understanding of the dynamics of star forming gas, while data from GES and Gaia are illuminating the kinematics of young stars and clusters. These observations all provide valuable tests of hydrodynamic and N-body simulations of these processes.

This meeting will be an important occasion bringing together observers and theorists to highlight the latest results on star and planet formation, make new connections and outline current challenges. We will also discuss new pathways for future observations with upcoming facilities such as JWST, LSST and the SKA.

TOPICS:

Molecular clouds and early-stage star formation
Magnetospheric accretion onto protostars
Kinematics and chemical evolution of proto-planetary disks and implications for planet formation
Dynamics of young stars and the formation of star clusters
The origin and role of feedback mechanisms such as outflows, stellar winds and UV radiation
Current (e.g., Herschel, ALMA, GES, MUSE, Gaia) and future (SKA, LSST, JWST) facilities

VENUE:

Metropolitan Hotel, Athens, Greece

HOW TO REGISTER / SUBMIT AN ABSTRACT:

The registration deadline is 4 July 2016, and the abstract submission deadline is 15 March 2016. Please visit the EWASS website to register and submit a contribution: http://eas.unige.ch/EWASS2016/registration.jsp

SOC:

Kanaris Tsinganos and Nick Wright (co-chairs), Francesca Bacciotti, Jim Dale, Odysseas Dionatos, Manuel Guedel, Richard Parker, Magnus Persson, Sarah Ragan, Tom Ray, Christophe Sauty, Rowan Smith, and Catherine Vlahakis.

Summary of Upcoming Meetings

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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