The Star Formation Newsletter

Editor: Bo Reipurth
reipurth@ifa.hawaii.edu

Technical Editor: Eli Bressert
ebressert@gmail.com

Technical Assistant: Hsi-Wei Yen
hwyen@asiaa.sinica.edu.tw

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

Newsletter Archive
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Cover Picture

The young star HL Tauri, located at a distance of 140 pc, is surrounded by a disk that is very bright at submm wavelengths. The cover picture shows the new ALMA 1.28 mm image obtained during the current long baseline campaign. The resolution is 35 milliarcseconds (~5 AU) and the image reveals many gaps in the disk, indicating that more massive bodies have already started forming even though HL Tau is likely not older than one million years. North is up and east is left.
For further details, see ESO Photo Release eso1436
Credit: ALMA (ESO/NAOJ/NRAO).

Submitting your abstracts

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each Call for Abstracts. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/star-formation/index.cfm
Q: What was your thesis about, what did you learn, and who was your adviser?

A: That was a long time ago! Looking back, I see that my thesis set the trajectory for the scientific path that I have meandered along through the intervening decades. At the University of Hawaii in the 1970s, graduate students had an amazing opportunity to use Mauna Kea’s then largest telescope, the UH 88-inch. My thesis was a study of the spectroscopic variability of the subset of T Tauri stars (TTS) then known as YY Ori stars, a class defined by Merle Walker as TTS that consistently showed inverse P Cygni profiles in some Balmer lines. Using a then state of the art image tube spectrograph with photographic plates as the detector, I was able to get red and blue spectra in pretty rapid succession of a number of YY Ori stars, showing that while they varied considerably on many timescales, they consistently showed P Cygni (outflow) signatures at H$\alpha$ and inverse P Cygni (infall) signatures in the upper Balmer lines. This was very mysterious at the time, as the concept of an accretion disk was lying in wait in a 1974 MNRAS paper by Lynden-Bell and Pringle while TTS properties were widely attributed to very active chromospheres and/or spherical circumsolar shells or envelopes.

My advisor was Ann Boesgaard, who was and is a leader in the study of light elements as a probe of stellar structure and evolution. She and I both got excited about T Tauri stars due to the presence of a regular visitor to Hawaii from Santa Cruz, her thesis advisor George Herbig. I became George’s observing assistant at Mauna Kea, and to this day feel unbelievably privileged to have spent so much time with him. Ann was a very supportive advisor who guided me through many rough times, and George was my inspiration. I learned so many things from him—such as how to look carefully at the richness and mystery of observational phenomena, and how to let them guide you to the next important question. He also taught me to refrain from the easy path of criticizing the work of others, but rather to look for the nugget of insight that was surely embedded in every paper. My thesis set the stage for my own lifelong interest in the relation between accretion and outflow in young stars, a connection that to this day is not really understood.

Q: In the early 1980s you were among the pioneers in studying molecular outflows from T Tauri stars and in association with Herbig-Haro objects. What were the main insights in the series of papers you wrote with Ron Snell?

A: Oh, that was a fun time! Ron and I were both newly arrived at the Five College Astronomy Department in western Massachusetts, Ron as a postdoc at the Five College Radio Astronomy Observatory (FCRAO) and me as an assistant professor at Smith College (my one and only job). Ron had just discovered the first bipolar molecular outflow, from L1551 IRS 5, and asked if I would like to join him in using the FCRAO telescope to look for further examples. We quickly realized that the presence of an HH object was a good way to sniff out molecular outflows from young stars. This ensured you were looking at the youngest, most active stars still embedded in natal gas that could then be swept up by a ‘T Tauri wind’. It provided a unique way to estimate mass loss rates from young stars, clarified the bipolar nature of the ejection, and gave an assessment of the energy and momentum being returned to the surrounding molecular gas.

Q: Your most cited paper is your 1987 study on forbidden line and H$\alpha$ profiles in T Tauri stars. What is the unique information that we get from such line profiles?

A: While both of these lines show kinematic features associated with mass loss, the forbidden lines are particularly powerful probes because they form so far from the star/disk interaction region. That 1987 paper was yet another fun project – a fruitful collaboration with Sylvie Cabrit, who was visiting me while still a graduate student at École Normale Supérieure, and Steve and Karen Strom, who had recently joined the Five College Astronomy Department. The predominantly blueshifted forbidden line emission coupled with the sizeable infrared excesses picked up by IRAS helped demonstrate the unequivocal evidence for disks around these low mass young stars, a conclusion already hinted at by Immo Appenzeller a few years earlier. The next paper in that series, led by Sylvie, clarified a proportional relation between luminosities in the forbidden lines and the infrared excesses – the first important step in showing the intimate connection between outflow and accretion. Forbidden lines have come back to haunt me every decade or so, including a 1995 study with Pat Hartigan where we clarified the dual origin T Tauri for-
bidden lines from both a high velocity collimated jet and a second low velocity wind, and defined an empirical relation between rates of accretion and outflow. And again now, with Ilaria Pascucci and Elisabetta Rigliaco, where we are finding that the low velocity component of the forbidden line emission likely comes from two distinct sources, possibly the disk surface and a photo-evaporative wind in the outer disk.

Q: Another highly cited study is your 1993 paper on angular momentum regulation in YSOs with circumstellar disks. This has become a field of great interest, how have your early results held up with time?

A: The evidence we presented in that paper, also recognized by Jerome Bouvier around the same time, suggested that as long as a circumstellar disk is still accreting, the central star is kept from spinning up even though it is both contracting and accreting material of high specific angular momentum from the inner Keplerian disk. It is gratifying to see that this basic conclusion has held up with time, although it has been questioned off and on, mostly because in working with large samples, distinguishing between young stars with and without accretion was tricky, and mass dependent effects needed to be accounted for. Of course, just how the accreting star avoids spinning up is still a mystery!

Q: Twenty years ago you used optical echelle spectra to search for infall and to test the magnetospheric accretion model for T Tauri stars.

A: Yes, this was revisiting my thesis work with better data and a clearer sense of the likely origin of the inverse P Cygni lines! A series of papers by Lee Hartmann, Nuria Calvet, and later also James Muzerolle, modeled line profile formation in accreting gas that follows the geometry of a magnetospheric dipole connecting the disk to the star. My observational work supported their ideas by showing that the basic line profile morphology was consistent with their models. Accretion is now better understood than winds, although I think there are still surprises in store here as well.

Q: You and John Kwan and other collaborators have focused much attention to helium lines, especially He I 10830, in T Tauri stars. Why is this line important?

A: Those other collaborators, by the way, were William Fischer, then a graduate student at UMass, and Lynne Hillenbrand. And yes, the 10830 Å line of neutral helium turns out to be an especially valuable probe of the geometry of the inner wind arising in the star-disk interaction region. This is due to its very high excitation potential, so it forms in a fairly localized region, and to its resonance scattering properties, so its very hard for a 1-micron photon to pass without being redirected. The line profiles demonstrate clearly that in some stars, even among those with the highest disk accretion rates, wind streamlines are directed radially away from the star, as in a stellar wind; while in others a stratified flow in a disk wind seems to be required. Overall, the diversity of He I profiles among TTS suggests something more than system inclination is implicated, although that certainly plays a role in whether radial or disk winds leave their mark on the line profile. For example, the nominally very young TTS HL Tau, whose dust disk structure was just revealed with ALMA (an astounding image!) shows unequivocal evidence at He I 10830 Å for a powerful wind emerging from the star-disk interaction region, not from the inner disk, but directed radially away from the star. From the inclination provided by the resolved disk we can infer that the accretion powered ‘stellar’ wind from HL Tau has an opening angle of at least 40°. In addition to what it will reveal about the evolution of disk structure and planet formation, ALMA will provide, for the first time, reliable disk inclinations for a large sample of TTS that will be crucial in interpreting these diagnostics of the inner wind.

Q: What are you currently working on?

A: Well, I guess I have to say I am still working on accretion and outflow in T Tauri stars! With increased spectral resolution and wavelength coverage, the problem gets more interesting and more complex. Its pretty clear now that most emission lines are composite in origin, so different components need to be isolated before line ratios can be compared with predictions from theoretical models, such as local line excitation calculations of John Kwan, or hydrodynamics and radiative transfer models by people like Ryuichi Kurosawa and Marina Romanova. The data is still speaking, and I am still trying to listen. One day we will know how the accretion-outflow connection really operates, how accretion powered winds are launched, what role they play in the angular momentum evolution of the star and the disk, and how these may affect the planet formation that is already underway.
1 Introduction

One of my favorite objects (although not the only one) is the Corona Australis star formation region. A detailed review of this target was presented by Neuhäuser & Forbrich (2008). Here I describe some of the particular aspects that have motivated me and my colleagues to study this region.

Corona Australis is one of the nearest star formation regions, at a distance of \( \approx 130 \) pc. Therefore, it is a prime target for studies that aim at including the faint young stellar object (YSO) population. The central sub-pc region, known as the Coronet cluster, has been extensively observed at all wavelengths from the radio to the X-rays (e.g., Choi et al. 2008; Lindberg et al. 2014; Peterson et al. 2011; Forbrich et al. 2007, and references therein). Here I use both names interchangeably. Figure 1 summarizes several aspects of this region: the cloud morphology revealed by dust in the far-infrared (Sicilia-Aguilar et al. 2013) is that of a ‘hub-filament’ system; one of the hubs still contains a large reservoir of cold gas and dust, as revealed by the sub-mm continuum; and this clump actually corresponds to the immediate environment of the YSOs in the Coronet Cluster.

Corona Australis has also been a target of choice for efforts in time monitoring of YSOs\(^1\). Suters et al. (1996) found variability in the radio emission, and Forbrich, Preibisch, & Menten (2006) found variability both in the radio and X-ray emission of the cluster members.

In 2012, together with Hauyu BaoBab Liu (ASIAA, Taiwan) and other colleagues, we started a time-monitoring campaign of YSOs. We are mainly taking advantage of the increased sensitivity of the upgraded Very Large Array (VLA) in the radio, but complement with new and archival near-infrared data. The main purpose of the project is to test the jet-accretion connection predicted by magnetohydrodynamical models of accretion and ejection of matter in YSOs (e.g., Shu et al. 1994). Clearly, Corona Australis had to be one of our targets: it is very close and the Coronet Cluster contains a relatively large number of YSOs (dozens) within a few arcminutes. These YSOs cover a large range of evolutionary stages and masses, from class 0 to class III objects, and from brown dwarfs to intermediate-mass stars (e.g., Acke & van den Ancker 2004, Sicilia-Aguilar et al. 2011).

2 Time monitoring of Young Stellar Objects in Corona Australis

The Coronet Cluster fits well within the primary beam (field of view) of the VLA. Therefore, we have been able to monitor it in the radio as often as 10 to 15 times per year with a modest time allocation (a few hours per semester for this field). Our first results were published early this year and contain the analysis of the radio variability in all the 2012 epochs (Liu et al. 2014), as well as a comparison with previous observations back to the 1990’s and infrared properties. Although most of the observations are in the same array configuration, we test for the convergence of the flux measurements cutting the shortest baselines. This means that we can address the variability of compact sources only. The results in Liu et al. (2014) can be summarized (see also Fig. 2) as follows:

- YSOs that are radio-bright (roughly, with 3.5 cm flux densities \( > 100 \) \( \mu \)Jy and detected in snapshot observations) tend to be either the youngest (class 0/I) or oldest objects. In other words, class II YSOs are radio faint (see Section 3).
- Radio-bright YSOs are significantly variable at all timescales from days to months to years. Some of them not only in total intensity but also in circularly polarized emission.
- Class 0 YSOs such as IRS 7E and IRS 7W have the lowest fractional flux variations in time lags \( \Delta t < 200 \) days and larger fractional variations in \( \Delta t > 1 \) year. In contrast, more evolved YSOs have significant extra variability on shorter timescales, down to \( \Delta t < 1 \) day. This result is consistent with the radio emission at the class 0 stage being dominated by

\(^1\)Actually, some of the brightest objects in the Coronet cluster are known to be variable since the early XX century. See Neuhäuser & Forbrich (2008).
free-free radiation from a jet, whereas at the class III stage it may be dominated by non-thermal (gyro)synchrotron radiation from an active stellar magnetosphere.

- There is a possible correlation between the ‘stable’ radio flux levels (once the variability is removed) and accretion rates derived from near-IR lines such as Brγ. Although this result needs further study, it may be interpreted as the expected correlation between accretion and jet ejection.

Some of these results have been shown in the past with a few observation epochs in selected objects (e.g., Anglada et al. 1998, Reipurth et al. 2004). However, thanks to the jump forward in sensitivity in the radio, we can now quantify it through systematic monitoring.

The next step is to include in the analysis the 2013 and 2014 VLA observations, as well as more near-IR data. In particular, we are very excited with a successful Very Large Telescope (VLT) K-band Multiobject Spectrograph (KMOS) program that has just finished last September. KMOS (Sharples et al. 2013) has 24 Integral Field Units (IFUs) that can be distributed within a patrol field of \(\sim 7\)°, which matches well our VLA primary beam. Figure 3 shows the location of the KMOS arms on the Coronet Cluster overlaid on a deep cm image, for one of our observing configurations. These quasi-simultaneous VLA/VLT observations will test the jet-accretion connection in YSOs.

### 3 Constraining photoevaporation in the Corona Australis protoplanetary disks

Besides the time variability studies, one of the main products of our VLA project in Corona Australis is a deep cm radio image that results from coadding all the observing epochs. This image gets deeper as the program runs, but this year we realized that it was deep enough to say something about photoevaporation of protoplanetary disks.

Gas-rich protoplanetary disks (i.e., primordial, pretransitional, and transitional disks, which approximately correspond to class II YSOs) are believed to be the sites of planet formation (e.g., Williams & Cieza 2011). There are tight observational constraints that set the lifetime of these disks to a few million years (e.g., Hernández et al. 2007). Photoevaporation by high-energy photons from the central star is one of the main mechanisms invoked to ac-
count for the dispersal of disks (Alexander et al. 2013, and references therein). In particular, extreme-UV photons reaching the disk produce free-free emission that ought to be detectable by deep VLA images such as ours of Corona Australis.

As mentioned above, Corona Australis has been observed by many researchers at multiple wavelengths. In particular, the disk population has been identified by studies in the near-IR with Spitzer and ground-based observatories and in the far-IR with Herschel (e.g., Currie & Sicilia Aguilar 2011, Sicilia-Aguilar et al. 2013). The stellar objects range from low-mass to intermediate-mass (for example, the well known T CrA and R CrA objects).

We searched for the radio emission from the ten disks within our VLA field of view and found that they tend to be quite faint: only three out of ten disks are detected at 3.5 cm. The implication for the non-detections is that the extreme-UV photon luminosity reaching the disk is $\Phi_{\text{EUV}} < 1 - 4 \times 10^{41} \text{ s}^{-1}$. These are relevant upper limits because they lie at the low-end of what many EUV-driven photoevaporation models require to clear disks within a few Myr (e.g., Alexander & Armitage 2009). These results are described in Galván-Madrid et al. (2014). Almost simultaneously, Pascucci et al. (2014) published a similar result based on observations of other fourteen protoplanetary disks.
Figure 3: Arrangement of the IFU arms of KMOS overlaid with the deep VLA map from Fig. 2. Our quasi-simultaneous VLA/VLT monitoring of Corona Australis has been running during 2014.

Table 1: Upper limits to the EUV-photon luminosity reaching the disks in the Coronet Cluster. 1: Detected object (not upper limit in flux density). Variable object. Upper limit to $\Phi_{\text{EUV}}$ obtained from the estimation of the ‘quiescent’ flux density measured in an image that included all the data from the epochs in which the source was individually not detected. Adapted from Galván-Madrid et al. (2014).

<table>
<thead>
<tr>
<th>Name</th>
<th>$\Phi_{\text{EUV}}$ [s$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-95</td>
<td>$&lt; 4.0 \times 10^{41}$</td>
</tr>
<tr>
<td>G-87</td>
<td>$&lt; 1.3 \times 10^{41}$</td>
</tr>
<tr>
<td>G-85</td>
<td>$&lt; 1.3 \times 10^{41}$</td>
</tr>
<tr>
<td>V709$^1$</td>
<td>$&lt; 1.1 \times 10^{42}$</td>
</tr>
<tr>
<td>HBC-677</td>
<td>$&lt; 1.0 \times 10^{41}$</td>
</tr>
<tr>
<td>IRS 8</td>
<td>$&lt; 2.7 \times 10^{41}$</td>
</tr>
<tr>
<td>R CrA$^1$</td>
<td>$&lt; 4.1 \times 10^{41}$</td>
</tr>
<tr>
<td>CrA-465</td>
<td>$&lt; 1.3 \times 10^{41}$</td>
</tr>
<tr>
<td>G-32</td>
<td>$&lt; 1.3 \times 10^{41}$</td>
</tr>
<tr>
<td>T CrA$^1$</td>
<td>$&lt; 3.8 \times 10^{41}$</td>
</tr>
</tbody>
</table>

For the three detections, because we have the time dimension information, we estimated their ‘quiescent’ flux densities by measuring them in an image including the data of all the epochs in which each source was not detected. It turns out that up to $\sim 40\%$ of the fluxes in the deepest image is due to rapidly varying emission, therefore unlikely to be due to free-free radiation from the photoevaporative flow, but rather (gyro)synchrotron emission. From these three objects, V709 is the brightest at 3.5 cm (average flux density of 892 $\mu$Jy) and is the only one that possibly is not a gas-rich disk but a debris disk. This again suggests that when detected, the cm emission is not dominated by photoevaporation.

As more epochs are coadded into the deep image, we will be able to put more stringent constraints on EUV-driven photoevaporation models, and also on X-ray driven photoevaporation. We will keep working on Corona Australis for the years to come.

I would like to thank Aurora Sicilia-Aguilar for the permission to reproduce adaptations of her published figures. The work presented here has significant contributions from Hauyu Baobab Liu, Jan Forbrich, Carlo Felice Manara, and Gráinne Costigan, as well as other collaborators.

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POISSON project: III. Investigating the evolution of the mass accretion rate.
S. Antoniucci\textsuperscript{1}, R. García López\textsuperscript{2}, B. Nisini\textsuperscript{1}, A. Caratti o Garatti\textsuperscript{2}, T. Giannini\textsuperscript{1} and D. Lorenzetti\textsuperscript{1}

\textsuperscript{1} INAF-Osservatorio Astronomico di Roma, Via Frascati 33, Monte Porzio Catone (RM), Italy
\textsuperscript{2} Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69,53121 Bonn, Germany

E-mail contact: simone.antoniucci at oa-roma.inaf.it

As part of the POISSON project (Protostellar Optical-Infrared Spectral Survey on NTT), we present the results of the analysis of low-resolution near-IR spectroscopic data (0.9-2.4 µm) of two samples of young stellar objects in the Lupus (52 objects) and Serpens (17 objects) star-forming clouds, with masses in the range of 0.1 to 2.0 M\textsubscript{☉} and ages spanning from 10\textsuperscript{5} to a few 10\textsuperscript{7} yr.

After determining the accretion parameters of the targets by analysing of their H I near-IR emission features, we added the results from the Lupus and Serpens clouds to those from previous regions (investigated in POISSON with the same methodology) to obtain a final catalogue (143 objects) of mass accretion rate values (\(\dot{M}_{\text{acc}}\)) derived in a homogeneous and consistent fashion. Our final goal is to analyse how \(\dot{M}_{\text{acc}}\) correlates with the stellar mass (\(M_\star\)) and how it evolves in time in the whole POISSON sample.

We derived the accretion luminosity (\(L_{\text{acc}}\)) and \(M_{\text{acc}}\) for Lupus and Serpens objects from the Br\(\gamma\) (Pa\(\beta\) in a few cases) line by using relevant empirical relationships available in the literature that connect H I line luminosity and \(L_{\text{acc}}\).

To minimise the biases that arise from adopting literature data that are based on different evolutionary models and also for self-consistency, we re-derived mass and age for each source of the POISSON samples using the same set of evolutionary tracks.

We observe a correlation \(\dot{M}_{\text{acc}}\sim M_\star^{2.2}\) between mass accretion rate and stellar mass, similarly to what has previously been observed in several star-forming regions. We find that the time variation of \(\dot{M}_{\text{acc}}\) is roughly consistent with the expected evolution of the accretion rate in viscous disks, with an asymptotic decay that behaves as \(t^{-1.6}\). However, \(\dot{M}_{\text{acc}}\) values are characterised by a large scatter at similar ages and are on average higher than the predictions of viscous models.

Although part of the scattering may be related to systematics due to the employed empirical relationship and to uncertainties on the single measurements, the general distribution and decay trend of the \(\dot{M}_{\text{acc}}\) points are real. These findings might be indicative of a large variation in the initial mass of the disks, of fairly different viscous laws among disks, of varying accretion regimes, and of other mechanisms that add to the dissipation of the disks, such as photo-evaporation.

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Planet-vortex interaction: How a vortex can shepherd a planetary embryo
S. Ataiee\textsuperscript{1,2,3}, C.P. Dullemond\textsuperscript{1}, W. Kley\textsuperscript{4}, Zs. Regály\textsuperscript{5}, and H. Meheut\textsuperscript{6}

\textsuperscript{1} Heidelberg University, Center for Astronomy, Institute for Theoretical Astrophysics, Albert Ueberle Str. 2, 69120 Heidelberg, Germany
\textsuperscript{2} School of Astronomy, Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
\textsuperscript{3} Department of Physics, Faculty of Sciences, Ferdowsi University of Mashhad, Mashhad, Iran
\textsuperscript{4} Institut für Astronomie & Astrophysik, Universität Tübingen, Auf der Morgenstelle 10, 72076, Tübingen, Germany
\textsuperscript{5} Konkoly Observatory, Research Center for Astronomy and Earth Science, Hungarian Academy of Sciences, Hungary
\textsuperscript{6} CEA, Irfu, SAp, Centre de Saclay, F-91191 Gif-sur-Yvette, France

E-mail contact: sareh.ataiee at gmail.com

Context: Anticyclonic vortices are considered as a favourable places for trapping dust and forming planetary embryos.
On the other hand, they are massive blobs that can interact gravitationally with the planets in the disc.

**Aims:** We aim to study how a vortex interacts gravitationally with a planet which migrates toward it or a planet which is created inside the vortex.

**Methods:** We performed hydrodynamical simulations of a viscous locally isothermal disc using GFARO and FARGO-ADSG. We set a stationary Gaussian pressure bump in the disc in a way that RWI is triggered. After a large vortex is established, we implanted a low mass planet in the outer disc or inside the vortex and allowed it to migrate. We also examined the effect of vortex strength on the planet migration and checked the validity of the final result in the presence of self-gravity.

**Results:** We noticed regardless of the planet’s initial position, the planet is finally locked to the vortex or its migration is stopped in a farther orbital distance in case of a stronger vortex. For the model with the weaker vortex, we studied the effect of different parameters such as background viscosity, background surface density, mass of the planet and different planet positions. In these models, while the trapping time and locking angle of the planet vary for different parameters, the main result, which is the planet-vortex locking, remains valid. We discovered that even a planet with a mass less than $5 \times 10^{-7} M_\odot$ comes out from the vortex and is locked to it at the same orbital distance. For a stronger vortex, both in non-self-gravitated and self-gravitating models, the planet migration is stopped far away from the radial position of the vortex. This effect can make the vortices a suitable place for continual planet formation under the condition that they save their shape during the planetary growth.

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**Kinematics in Partially Ionised Molecular Clouds: Implications for the Transition to Coherence**

Nicole D. Bailey\(^1,2\), Shantanu Basu\(^3\) and Paola Caselli\(^1,2\)

\(^1\) Max-Planck-Institut für extraterrestrische Physik, Giessenbachstrasse 1, 85748 Garching, Germany
\(^2\) School of Physics and Astronomy, University of Leeds, Leeds, United Kingdom, LS2 9JT
\(^3\) Department of Physics and Astronomy, University of Western Ontario, 1151 Richmond Street, London, Ontario, Canada, N6A 3K7

E-mail contact: ndbailey at mpe.mpg.de

Bailey & Basu (2014) show analysis of density and mass-to-flux ratio maps for simulations with either an ionisation profile which takes into account photoionisation (step-like profile) or a cosmic ray only ionisation profile. We extend this study to analyse the effect of these ionisation profiles on velocity structures, kinematics, and synthetic spectra. Clump regions are found to occur at the convergence of two flows with a low velocity region and velocity direction transition occurring at the junction. Models with evident substructure show that core formation occurs on the periphery of these velocity valleys. Analysis of synthetic spectra reveals the presence of large non-thermal components within low-density gas, especially for models with the step-like ionisation profile. All cores show small, sub-thermal relative motions compared to background gas. Large deviations within this analysis are due to the line of sight intersecting low- and high-density regions across the velocity switch transition. Positive deviations correspond to a foreground core moving away from the observer while negative deviations correspond to a background core moving toward the observer. Comparison of velocities resulting from different ionisation profiles suggest that high ionisation fractions yield supersonic velocities, up to two times the sound speed, while regions with low ionisation fractions tend to be subsonic or mildly supersonic. This suggests that the transition to coherence within cores could be a transition between high and low ionisation fractions within the gas.

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**The Fate of Scattered Planets**

Benjamin C. Bromley\(^1\) and Scott J. Kenyon\(^2\)

\(^1\) Department of Physics & Astronomy, University of Utah, 115 S 1400 E, Rm 201, Salt Lake City, UT 84112, USA
\(^2\) Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, MA 02138, USA
E-mail contact: bromley at physics.utah.edu

As gas giant planets evolve, they may scatter other planets far from their original orbits to produce hot Jupiters or rogue planets that are not gravitationally bound to any star. Here, we consider planets cast out to large orbital distances on eccentric, bound orbits through a gaseous disk. With simple numerical models, we show that super-Earths can interact with the gas through dynamical friction to settle in the remote outer regions of a planetary system. Outcomes depend on planet mass, the initial scattered orbit, and the evolution of the time-dependent disk. Efficient orbital damping by dynamical friction requires planets at least as massive as the Earth. More massive, longer-lived disks damp eccentricities more efficiently than less massive, short-lived ones. Transition disks with an expanding inner cavity can circularize orbits at larger distances than disks that experience a global (homologous) decay in surface density. Thus, orbits of remote planets may reveal the evolutionary history of their primordial gas disks. A remote planet with an orbital distance ~100 AU from the Sun is plausible and might explain correlations in the orbital parameters of several distant trans-Neptunian objects.

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A near-IR spectroscopic survey of massive jets towards EGOs

A. Caratti o Garatti1, B. Stecklum2, H. Linz3, R. Garcia Lopez1 and A. Sanna1

1 Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
2 Thüringer Landessternwarte Tautenburg, Sternwarte 5, D-07778 Tautenburg, Germany
3 Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

E-mail contact: acaratti at mpifr-bonn.mpg.de

Protostellar jets and outflows are the main outcome of the star formation process, and their analysis can provide us with major clues about the ejection and accretion history of young stellar objects (YSOs). We aim at deriving the main physical properties of massive jets from near-IR (NIR) observations, comparing them to those of a large sample of jets from low-mass YSOs, and relating them to the main features of their driving sources. We present a NIR imaging (H2 and Ks) and low-resolution spectroscopic (0.95-2.50 µm) survey of 18 massive jets towards GLIMPSE extended green objects (EGOs), driven by intermediate- and high-mass YSOs, which have bolometric luminosities (Lbol) between 4×102 and 1.3×105 L⊙. As in low-mass jets, H2 is the primary NIR coolant, detected in all the analysed flows, whereas the most important ionic tracer is [FeII], detected in half of the sampled jets. Our analysis indicates that the emission lines originate from shocks at high temperatures and densities. No fluorescent emission is detected along the flows, regardless of the source bolometric luminosity. On average, the physical parameters of these massive jets (i.e. visual extinction, temperature, column density, mass, and luminosity) have higher values than those measured in their low-mass counterparts. The morphology of the H2 flows is varied, mostly depending on the complex, dynamic, and inhomogeneous environment in which these massive jets form and propagate. All flows and jets in our sample are collimated, showing large precession angles. Additionally, the presence of both knots and jets suggests that the ejection process is continuous with burst episodes, as in low-mass YSOs. We compare the flow H2 luminosity with the source bolometric luminosity confirming the tight correlation between these two quantities. Five sources, however, display a lower LH2/Lbol efficiency, which might be related to YSO evolution. Most important, the inferred LH2 vs. Lbol relationship agrees well with the correlation between the momentum flux of the CO outflows and the bolometric luminosities of high-mass YSOs indicating that outflows from high-mass YSOs are momentum driven, as are their low-mass counterparts. We also derive a less stringent correlation between the inferred mass of the H2 flows and Lbol of the YSOs, indicating that the mass of the flow depends on the driving source mass. By comparing the physical properties of jets in the NIR, a continuity from low- to high-mass jets is identified. Massive jets appear as a scaled-up version of their low-mass counterparts in terms of their physical parameters and origin. Nevertheless, there are consistent differences such as a more variegated morphology and, on average, stronger shock conditions, which are likely due to the different environment in which high-mass stars form.

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Diagnosing Mass Flows Around Herbig Ae/Be Stars Using the He I 10830 Line

P. Wilson Cauley\textsuperscript{1} and Christopher M. Johns–Krull\textsuperscript{2}

\textsuperscript{1} Wesleyan University and Department of Astronomy, 45 Wyllys Avenue, Middletown, CT 06459, USA
\textsuperscript{2} Rice University and Department of Physics and Astronomy, 6100 Main St., MS 108, Houston, TX 77005, USA

E-mail contact: pcauley at wesleyan.edu

We examine He I 10830 profile morphologies for a sample of 56 Herbig Ae/Be stars (HAEBES). We find significant differences between HAEBES and CTTSs in the statistics of both blue-shifted absorption (i.e. mass outflows) and red-shifted absorption features (i.e. mass infall or accretion). Our results suggest that, in general, Herbig Be (HBe) stars do not accrete material from their inner disks in the same manner as CTTSs, which are believed to accrete material via magnetoospheric accretion, while Herbig Ae (HAe) stars generally show evidence for magnetoospheric accretion. We find no evidence in our sample of narrow blue–shifted absorption features which are typical indicators of inner disk winds and are common in He I 10830 profiles of CTTSs. The lack of inner disk wind signatures in HAEBES, combined with the paucity of detected magnetic fields on these objects, suggests that accretion through large magnetoospheres which truncate the disk several stellar radii above the surface is not as common for HAe and late-type HBe stars as it is for CTTSs. Instead, evidence is found for smaller magnetoospheres in the maximum red-shifted absorption velocities in our HAEBE sample. These velocities are, on average, a smaller fraction of the system escape velocity than is found for CTTSs, suggesting accretion is taking place closer to the star. Smaller magnetoospheres, and evidence for boundary layer accretion in HBe stars, may explain the less common occurrence of red–shifted absorption in HAEBES. Evidence is found that smaller magnetoospheres may be less efficient at driving outflows compared to CTTS magnetoospheres.

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Transition from the Infalling Envelope to the Keplerian Disk around L1551 IRS 5

Ti-Lin Chou\textsuperscript{1,2}, Shigehisa Takakuwa\textsuperscript{2}, Hsi-Wei Yen\textsuperscript{2}, Nagayoshi Ohashi\textsuperscript{2,3} and Paul T. P. Ho\textsuperscript{2,4}

\textsuperscript{1} Department of Physics, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei 106, Taiwan;
\textsuperscript{2} Academia Sinica Institute of Astronomy and Astrophysics, P. O. Box 23-141, Taipei 10617, Taiwan
\textsuperscript{3} Subaru Telescope, National Astronomical Observatory of Japan, 650 North A’ohoku Place, Hilo, HI 96720, USA
\textsuperscript{4} Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: tlchou at asiaa.sinica.edu.tw

We present combined SubMillimeter Array (SMA) + Atacama Submillimeter Telescope Experiment (ASTE) images of the Class I protobinary L1551 IRS 5 in the CS ($J = 7-6$) line, the submillimeter images of L1551 IRS 5 with the most complete spatial sampling ever achieved (0\textdegree.9 – 36\textdegree). The SMA image of L1551 IRS 5 in the 343 GHz dust-continuum emission is also presented, which shows an elongated feature along the northwest to southeast direction (~160 AU × 80 AU), perpendicular to the associated radio jets. The combined SMA+ASTE images show that the high-velocity ($\geq$1.5 km s$^{-1}$) CS emission traces the structure of the dust component and shows a velocity gradient along the major axis, which is reproduced by a geometrically-thin Keplerian-disk model with a central stellar mass of ~0.5 $M_\odot$. The low-velocity ($\leq$1.3 km s$^{-1}$) CS emission shows an extended (~1000 AU) feature that exhibits slight south (blueshifted) to north (redshifted) emission offsets, which is modeled with a rotating and infalling envelope with a conserved angular momentum. The rotational motion of the envelope connects smoothly to the inner Keplerian rotation at a radius of ~64 AU. The infalling velocity of the envelope is ~three times lower than the free-fall velocity toward the central stellar mass of 0.5 $M_\odot$. These results demonstrate transition from the infalling envelope to the Keplerian disk, consistent with the latest theoretical studies of disk formation. We suggest that sizable ($r$ ~50–200 AU) Keplerian disks are already formed when the protostars are still deeply embedded in the envelopes.

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A Pulsation Search Among Young Brown Dwarfs and Very Low Mass Stars

Ann Marie Cody\textsuperscript{1,2} and Lynne A. Hillenbrand\textsuperscript{2}

\textsuperscript{1} Spitzer Science Center, California Institute of Technology, 1200 E California Blvd., Pasadena, CA 91125, USA
\textsuperscript{2} California Institute of Technology, Department of Astrophysics, MC 249-17, Pasadena, CA 91125, USA

E-mail contact: annmarie.cody at nasa.gov

In 2005, Palla & Baraffe proposed that brown dwarfs (BDs) and very low mass stars (VLMSs; $<0.1 \, M_{\odot}$) may be unstable to radial oscillations during the pre-main-sequence deuterium burning phase. With associated periods of 1–4 hours, this potentially new class of pulsation offers unprecedented opportunities to probe the interiors and evolution of low-mass objects in the 1–15 million year age range. Following up on reports of short-period variability in young clusters, we designed a high-cadence photometric monitoring campaign to search for deuterium-burning pulsation among a sample of 348 BDs and VLMSs in the four young clusters Sigma Orionis, Chamaeleon I, IC 348, and Upper Scorpius. In the resulting light curves we achieved sensitivity to periodic signals of amplitude several millimagnitudes, on timescales from 15 minutes to two weeks. Despite the exquisite data quality, we failed to detect any periodicities below seven hours. We conclude that D-burning pulsations are not able to grow to observable amplitudes in the early pre-main sequence. In spite of the non-detection, we did uncover a rich set of variability behavior—both periodic and aperiodic—on day to week timescales. We present new compilations of variable sources from our sample, as well as three new candidate cluster members in Chamaeleon I.

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G11.92-0.61-MM2: A Bonafide Massive Prestellar Core?

C. J. Cyganowski\textsuperscript{1,2}, C. L. Brogan\textsuperscript{3}, T. R. Hunter\textsuperscript{3}, D. Graninger\textsuperscript{2}, K. I. Oberg\textsuperscript{2}, A. Vasyunin\textsuperscript{4,5,6}, Q. Zhang\textsuperscript{2}, R. Friesen\textsuperscript{7} and S. Schnee\textsuperscript{3}

\textsuperscript{1} Scottish Universities Physics Alliance (SUPA), School of Physics and Astronomy, University of St. Andrews, North Haugh, St Andrews, Fife KY16 9SS, UK
\textsuperscript{2} Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA
\textsuperscript{3} NRAO, 520 Edgemont Rd, Charlottesville, VA 22903, USA
\textsuperscript{4} School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, UK
\textsuperscript{5} Max-Planck-Institut für Extraterrestrische Physik (MPE), Giessenbachstr.1, D-85748 Garching, Germany
\textsuperscript{6} Ural Federal University, Ekaterinburg, Russia
\textsuperscript{7} Dunlap Institute for Astronomy and Astrophysics, University of Toronto, 50 St George St., Toronto, ON M5S 3H4, Canada

E-mail contact: cc243 at st-andrews.ac.uk

Core accretion models of massive star formation require the existence of stable massive starless cores, but robust observational examples of such objects have proven elusive. We report subarcsecond-resolution SMA 1.3 mm, 1.1 mm, and 0.88 mm and VLA 1.3 cm observations of an excellent massive starless core candidate, G11.92−0.61–MM2, initially identified in the course of studies of GLIMPSE Extended Green Objects (EGOs). Separated by $\sim$7.2“ from the nearby MM1 protostellar hot core, MM2 is a strong, compact dust continuum source (submillimeter spectral index $\alpha =2.6\pm0.1$), but is devoid of star formation indicators. In contrast to MM1, MM2 has no masers, no centimeter continuum, and no (sub)millimeter wavelength line emission in $\sim$24 GHz of bandwidth observed with the SMA, including $N_2H^+$(3-2), HCO$^+$(3-2), and HCN(3-2). Additionally, there is no evidence for an outflow driven by MM2. The (sub)millimeter spectral energy distribution (SED) of MM2 is best fit with a dust temperature of $\sim$17-19 K and luminosity of $\sim$5-7 $L_{\odot}$. The combined physical properties of MM2, as inferred from its dust continuum emission, are extreme: $M>30 \, M_{\odot}$ within a radius$<1000$ AU, $N_{\text{H}_2}>10^{25}$ cm$^{-2}$ and $n_{\text{H}_2}>10^9$ cm$^{-3}$. Comparison of the molecular abundance limits derived from our SMA observations with gas-grain chemical models indicates that extremely dense ($n(\text{H})>>10^8$ cm$^{-3}$), cold ($<20$ K) conditions are required to explain the lack of observed (sub)millimeter line emission, consistent with the dust continuum results. Our data suggest that G11.92−0.61–MM2 is the best candidate for a bonafide massive prestellar core found to date, and a promising target for future, higher-sensitivity observations.

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Star formation around the mid-infrared bubble CN 148

L. K. Dewangan\textsuperscript{1}, D. K. Ojha\textsuperscript{2}, J. M. C. Grave\textsuperscript{1,3} and K. K. Mallick\textsuperscript{2}

\textsuperscript{1} Centro de Astrofísica, Universidade do Porto, Rua das Estrelas, 4150-762 s/n Porto, Portugal
\textsuperscript{2} Department of Astronomy and Astrophysics, Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India
\textsuperscript{3} FCNET, Universidade Lusófona do Porto, Rua Augusto Rosa 24, 4000-098, Porto, Portugal

E-mail contact: Lokesh.Dewangan \textsuperscript{at} astro.up.pt

We present a multi-wavelength study to analyse the star formation process associated with the mid-infrared bubble CN 148 (H\textsc{ii} region G10.3-0.1), which harbors an O5V-O6V star. The arc-shaped distribution of molecular CO(2-1) emission, the cold dust emission, and the polycyclic aromatic hydrocarbon features trace a photodissociation region (PDR) around the H\textsc{ii} region. We have identified 371 young stellar objects (YSOs) in the selected region and, interestingly, their spatial distribution correlates well with the PDR. 41\% of these YSOs are present in 13 clusters, each having visual extinction larger than 16 mag. The clusters at the edges of the bubble (both northeast and southwest) are found to be relatively younger than the clusters located further away from the bubble. We also find that four 6.7 GHz methanol masers, two Extended Green Objects, an ultra-compact H\textsc{ii} region, and a massive protostar candidate (as previously reported) are spatially positioned at the edges of the bubble. The existence of an apparent age gradient in YSO clusters and different early evolutionary stages of massive star formation around the bubble suggest their origin to be influenced by an H\textsc{ii} region expanding into the surrounding interstellar medium. The data sets are suggestive of triggered star formation.

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Colliding Filaments and a Massive Dense Core in the Cygnus OB 7 Molecular Cloud

Kazuhito Dobashi\textsuperscript{1}, Tomoaki Matsumoto\textsuperscript{2}, Tomomi Shimoikura\textsuperscript{1}, Hiro Saito\textsuperscript{3}, Ko Akisato\textsuperscript{1}, Kenjiro Ohashi\textsuperscript{1} and Keisuke Nakagomi\textsuperscript{1}

\textsuperscript{1} Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Koganei, Tokyo 184-8501, Japan
\textsuperscript{2} Department of Humanity and Environment, Hosei University, Fujimi, Chiyoda-ku, Tokyo 102-8160, Japan
\textsuperscript{3} National Astronomical Observatory of Japan, Mitaka, Tokyo 181-8588, Japan

E-mail contact: dobashi \textsuperscript{at} u-gakugei.ac.jp

We report results of molecular line observations carried out toward a massive dense core in the Cyg OB 7 molecular cloud. The core has an extraordinarily large mass (\(\sim 1.1 \times 10^4 \ M_\odot\)) and size (\(\sim 2 \times 5 \ \text{pc}^2\)), but there is no massive young star forming therein. We observed this core in various molecular lines such as C\textsuperscript{18}O(\(J = 1 \rightarrow 0\)) using the 45m telescope at Nobeyama Radio Observatory. We find that the core has an elongated morphology consisting of several filaments and core-like structures. The filaments are massive (\(10^2 - 10^3 \ M_\odot\)), and they are apparently colliding against each other. Some candidates of YSOs are distributed around their intersection, suggesting that the collisions of the filaments may have influenced on their formation. To understand the formation and evolution of such colliding filaments, we performed numerical simulations using the adaptive mesh refinement (AMR) technique adopting the observed core parameters (e.g., the mass and size) as the initial conditions. Results indicate that the filaments are formed as seen in other earlier simulations for small cores in literature, but we could not reproduce the collisions of the filaments simply by assuming the large initial mass and size. We find that the collisions of the filaments occur only when there is a large velocity gradient in the initial core in a sense to compress it. We suggest that the observed core was actually compressed by an external effect, e.g., shocks of nearby supernova remnants including HB21 which has been suggested to be interacting with the Cyg OB 7 molecular cloud.

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Can dust coagulation trigger streaming instability?

Joanna Drążkowska¹ and Cornelis P. Dullemond¹

¹ Heidelberg University, Center for Astronomy, Institute of Theoretical Astrophysics, Albert-Ueberle-Str. 2, 69120 Heidelberg, Germany

E-mail contact: drazkowska at uni-heidelberg.de

Streaming instability can be a very efficient way of overcoming growth and drift barriers to planetesimal formation. However, it was shown that strong clumping, which leads to planetesimal formation, requires a considerable number of large grains. State-of-the-art streaming instability models do not take into account realistic size distributions resulting from the collisional evolution of dust. We investigate whether a sufficient quantity of large aggregates can be produced by sticking and what the interplay of dust coagulation and planetesimal formation is. We develop a semi-analytical prescription of planetesimal formation by streaming instability and implement it in our dust coagulation code based on the Monte Carlo algorithm with the representative particles approach. We find that planetesimal formation by streaming instability may preferentially work outside the snow line, where sticky icy aggregates are present. The efficiency of the process depends strongly on local dust abundance and radial pressure gradient, and requires a supersolar metallicity. If planetesimal formation is possible, the dust coagulation and settling typically need ~100 orbits to produce sufficiently large and settled grains and planetesimal formation lasts another ~1000 orbits. We present a simple analytical model that computes the amount of dust that can be turned into planetesimals given the parameters of the disk model.

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Possible Planet formation in the young, low-mass, multiple stellar system GG Tau-A

Anne Dutrey¹, Emmanuel DiFolco¹, Stephane Guilloteau¹, Yann Boheler², Jeff Bary³, Tracy Beck⁴, Herve Beust⁵, Edwige Chapillon¹⁶, Frederic Gueth⁶, Jean-Marc Huré¹, Arnaud Pierens¹, Vincent Pietu⁶, Michal Simon⁷ and Ya-Wen Tang⁸

¹ Univ. Bordeaux, LAB, UMR 5804, F-33270, Floirac, France and CNRS, LAB, UMR 5804, F-33270 Floirac, France
² CRyA, University of Mexico, Apartado Postal 3-72, 58089 Morelia, Michoacan, Mexico
³ Department of Physics and Astronomy, Colgate University, 13 Oak Drive, Hamilton, NY 13346, USA
⁴ Space Telescope Science Institute, 3700 san Martin Dr. Baltimore, MD 21218, USA
⁵ IPAG, UMR 5274, BP 53, F-38041 Grenoble Cedex 9, France
⁶ IRAM, 300 rue de la Piscine, F-38046 Saint Martin d’Hères, France
⁷ Stony Brook University, Stony Brook, NY 11794-3800, USA
⁸ Academia Sinica Institute of Astronomy and Astrophysics, P.O. Box 23-141, Taipei, 106 Taiwan

E-mail contact: anne.dutrey at obs.u-bordeaux1.fr

Forming planets around binary stars may be more difficult than around single stars. In a close binary star (< 100 au separation), theory predicts the presence of circumstellar discs around each star, and an outer circumbinary disc surrounding a gravitationally cleared inner cavity. As the inner discs are depleted by accretion onto the stars on timescales of few 10³ yr, replenishing material must be transferred from the outer reservoir in order to fuel planet formation (which occurs on timescales of ~1 Myr). Gas flowing through disc cavities has been detected in single star systems. A circumbinary disc was discovered around the young low-mass binary system GG Tau-A, which has recently been proven to be a hierarchical triple system. It has one large inner disc around the southern single star and shows small amounts of shocked H₂ gas residing within the central cavity, but other than a weak detection, hitherto the distribution of cold gas in this cavity or in any other binary or multiple star system has never been determined. Here we report imaging of massive CO-emitting gas fragments within the GG Tau-A cavity. From the kinematics we conclude that the flow appears capable of sustaining the inner disc beyond the accretion lifetime, leaving time for planet formation to occur.

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A near-infrared interferometric survey of debris-disk stars.
IV. An unbiased sample of 92 southern stars observed in H band with VLTI/PIONIER

S. Ertel¹,², O. Absil³, D. Defrèere⁴, J.-B. Le Bouquin¹, J.-C. Augereau¹, L. Marion³, N. Blind⁵, A. Bonsor⁶, G. Bryden⁷, J. Lebreton⁸,⁹ and J. Milli¹,²

¹ Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France
² CNRS, IPAG, F-38000 Grenoble, France
³ European Southern Observatory, Alonso de Cordova 3107, Vitacura, Casilla 19001, Santiago 19, Chile
⁴ Département d’Astrophysique, Géophysique et Océanographie, Université de Liège, Allée du Six Août 17, 4000 Liège, Belgium
⁵ Department of Astronomy, University of Arizona, 993 N. Cherry Ave, Tucson, AZ 85721, USA
⁶ Max Planck Institute for Extraterrestrial Physics, Gießenbachstraße, 85741 Garching, Germany
⁷ School of Physics, H. H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, UK
⁸ Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
⁹ Infrared Processing and Analysis Center, California Institute of Technology, Pasadena, CA 91125, USA
¹⁰ NASA Exoplanet Science Institute, California Institute of Technology, 770 S. Wilson Ave., Pasadena, CA 91125, USA

E-mail contact: sertel at eso.org

Context: Detecting and characterizing circumstellar dust is a way to study the architecture and evolution of planetary systems. Cold dust in debris disks only traces the outer regions. Warm and hot exozodiacal dust needs to be studied in order to trace regions close to the habitable zone.

Aims: We aim to determine the prevalence and to constrain the properties of hot exozodiacal dust around nearby main-sequence stars.

Methods: We searched a magnitude-limited ($H \leq 5$) sample of 92 stars for bright exozodiacal dust using our VLTI visitor instrument PIONIER in the H band. We derived statistics of the detection rate with respect to parameters, such as the stellar spectral type and age or the presence of a debris disk in the outer regions of the systems. We derived more robust statistics by combining our sample with the results from our CHARA/FLUOR survey in the K band. In addition, our spectrally dispersed data allowed us to put constraints on the emission mechanism and the dust properties in the detected systems.

Results: We find an overall detection rate of bright exozodiacal dust in the H band of 11% (9 out of 85 targets) and three tentative detections. The detection rate decreases from early type to late type stars and increases with the age of the host star. We do not confirm the tentative correlation between the presence of cold and hot dust found in our earlier analysis of the FLUOR sample alone. Our spectrally dispersed data suggest that either the dust is extremely hot or the emission is dominated by the scattered light in most cases. The implications of our results for the target selection of future terrestrial planet-finding missions using direct imaging are discussed.

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¹³C-methyl formate: observations of a sample of high mass star-forming regions including Orion-KL and spectroscopic characterization

Cécile Favre¹, Miguel Carvajal², David Field³, Jes K. Jørgensen⁴,⁵, Suzanne E. Bisschop⁴,⁵, Nathalie Brouillet⁶,⁷, Didier Despois⁶,⁷, Alain Baudry⁶,⁷, Isabelle Kleiner³, Edwin A. Bergin³, Nathan R. Crockett³, Justin L. Neill³, Laurent Margulès⁸, Thérèse R. Huet⁹, Jean Demaison¹⁰

¹ Department of Astronomy, University of Michigan, 500 Church St., Ann Arbor, MI 48109, USA
² Dpto. Física Aplicada, Unidad Asociada CSIC, Facultad de Ciencias Experimentales, Universidad de Huelva, 21071, Spain
³ Department of Physics and Astronomy, University of Aarhus, Ny Munkegade 120, 8000 Aarhus C, Denmark
⁴ Centre for Star and Planet Formation, Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, 2100 Copenhagen Ø, Denmark
⁵ Natural History Museum of Denmark, University of Copenhagen, Øster Voldgade 5-7, 1350 Copenhagen K., Denmark
⁶ Univ. Bordeaux, LAB, UMR 5804, F-33270, Floirac, France
⁷ CNRS, LAB, UMR 5804, F-33270, Floirac, France
We have surveyed a sample of massive star-forming regions located over a range of distances from the Galactic centre for methyl formate, HCOOCH₃, and its isotopologues H¹³COOCH₃ and HCOO¹³CH₃. The observations were carried out with the APEX telescope in the frequency range 283.4–287.4 GHz. Based on the APEX observations, we report tentative detections of the ¹³C-methyl formate isotopologue HCOO¹³CH₃ towards the following four massive star-forming regions: Sgr B2(N-LMH), NGC 6334 IRS 1, W51 e2 and G19.61–0.23. In addition, we have used the 1 mm ALMA science verification observations of Orion-KL and confirm the detection of the ¹³C-methyl formate species in Orion-KL and image its spatial distribution. Our analysis shows that the ¹²C/¹³C isotope ratio in methyl formate toward Orion-KL Compact Ridge and Hot Core-SW components (68.4±10.1 and 71.4±7.8, respectively) are, for both the ¹³C-methyl formate isotopologues, commensurate with the average ¹²C/¹³C ratio of CO derived toward Orion-KL. Likewise, regarding the other sources, our results are consistent with the ¹²C/¹³C in CO. We also report the spectroscopic characterization, which includes a complete partition function, of the complex H¹³COOCH₃ and HCOO¹³CH₃ species. New spectroscopic data for both isotopomers H¹³COOCH₃ and HCOO¹³CH₃, presented in this study, has made it possible to measure this fundamentally important isotope ratio in a large organic molecule for the first time.

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Simulated Performance of Timescale Metrics for Aperiodic Light Curves

Krzysztof Findeisen¹, Ann Marie Cody¹,² and Lynne A. Hillenbrand¹

¹ Cahill Center for Astronomy and Astrophysics, California Institute of Technology, MC 249-17, Pasadena, CA 91125, USA
² Spitzer Science Center, California Institute of Technology, MC 314-6, Pasadena, CA 91125, USA

E-mail contact: krzys at astro.caltech.edu

Aperiodic variability is a characteristic feature of young stars, massive stars, and active galactic nuclei. With the recent proliferation of time domain surveys, it is increasingly essential to develop methods to quantify and analyze aperiodic variability. We develop three timescale metrics that have been little used in astronomy – ∆m-∆t plots, peak-finding, and Gaussian process regression – and present simulations comparing their effectiveness across a range of aperiodic light curve shapes, characteristic timescales, observing cadences, and signal to noise ratios. We find that Gaussian process regression is easily confused by noise and by irregular sampling, even when the model being fit reflects the process underlying the light curve, but that ∆m-∆t plots and peak-finding can coarsely characterize timescales across a broad region of parameter space. We make public the software we used for our simulations, both in the spirit of open research and to allow others to carry out analogous simulations for their own observing programs.

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Revealing H₂D⁺ depletion and compact structure in starless and protostellar cores with ALMA

R. K. Friesen¹, J. Di Francesco²,³, T. L. Bourke⁴, P. Caselli⁵,⁶, J. K. Jørgensen⁷,⁸, J. E. Pineda⁹ and M. Wong¹⁰

¹ Dunlap Institute for Astronomy & Astrophysics, University of Toronto, 50 St George St, Toronto, ON, M5S 3H4, Canada
² National Research Council Canada, Radio Astronomy Program, 5071 West Saanich Rd, Victoria, BC, V9E 2E7, Canada
We present Atacama Large Millimeter/submillimeter Array (ALMA) observations of the submillimeter dust continuum and H$_2$D$^+$ 1$_{10}$ − 1$_{11}$ emission toward two evolved, potentially protostellar cores within the Ophiuchus molecular cloud, Oph A SM1 and SM1N. The data reveal small-scale condensations within both cores, with mass upper limits of $M < \sim 0.02$ M$_\odot$ ($\sim 20$ M$_{\text{Jup}}$). The SM1 condensation is consistent with a nearly-symmetric Gaussian source with a width of only 37 AU. The SM1N condensation is elongated, and extends 500 AU along its major axis. No evidence for substructure is seen in either source. A Jeans analysis indicates these sources are unlikely to fragment, suggesting that both will form single stars. H$_2$D$^+$ is only detected toward SM1N, offset from the continuum peak by $\sim 150$ − 200 AU. This offset may be due to either heating from an undetected, young, low luminosity protostellar source or first hydrostatic core, or HD (and consequently H$_2$D$^+$) depletion in the cold centre of the condensation. We propose that SM1 is protostellar, and that the condensation detected by ALMA is a warm ($T \sim 30$ − 50 K) accretion disk. The less concentrated emission of the SM1N condensation suggests that it is still starless, but we cannot rule out the presence of a low-luminosity source, perhaps surrounded by a pseudodisk. These data reveal observationally the earliest stages of the formation of circumstellar accretion regions, and agree with theoretical predictions that disk formation can occur very early in the star formation process, coeval with or just after the formation of a first hydrostatic core or protostar.

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Effects of dust feedback on vortices in protoplanetary disks

Wen Fu$^{1,2}$, Hui Li$^2$, Stephen Lubow$^3$, Shengtai Li$^2$, Edison Liang$^1$

$^1$ Department of Physics and Astronomy, Rice University, Houston, TX 77005, USA
$^2$ Los Alamos National Laboratory, Los Alamos, NM 87545, USA
$^3$ Space Telescope Science Institute, Baltimore, MD 21218, USA

E-mail contact: wf5 at rice.edu

We carried out two-dimensional high-resolution simulations to study the effect of dust feedback on the evolution of vortices induced by massive planets in protoplanetary disks. Various initial dust to gas disk surface density ratios (0.001 − 0.01) and dust particle sizes (Stokes number $4 \times 10^{-4}$ − 0.16) are considered. We found that while dust particles migrate inwards, vortices are very effective in collecting them. When dust density becomes comparable to gas density within the vortex, a dynamical instability is excited and it alters the coherent vorticity pattern and destroys the vortex. This dust feedback effect is stronger with higher initial dust/gas density ratio and larger dust grain. Consequently, we found that the disk vortex lifetime can be reduced up to a factor of 10. We discuss the implications of our findings on the survivability of vortices in protoplanetary disks and planet formation.

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Formation of young massive clusters from turbulent molecular clouds

Michiko S. Fujii$^1$

$^1$ Division of Theoretical Astronomy, National Astronomical Observatory of Japan, 2211 Osawa, Mitaka-shi, Tokyo
Young massive clusters are as young as open clusters but more massive and compact compared with typical open clusters. The formation process of young massive clusters is still unclear, and it is an open question whether the formation process is the same as typical open clusters or not. We perform a series of N-body simulations starting from initial conditions constructed from the results of hydrodynamical simulations of turbulent molecular clouds. In our simulations, both open clusters and young massive clusters form when we assume a density-dependent star formation efficiency. We find that a local star formation efficiency higher than 50% is necessary for the formation of young massive clusters, but open clusters forms from less dense regions with a local star formation efficiency of <50%. We confirm that the young massive clusters formed in our simulations have mass, size, and density profile similar to those of observed young massive clusters such as NGC 3603 and Trumpler 14. We also find that these simulated clusters evolve via hierarchical mergers of sub-clusters within a few Myr, as is suggested by recent simulations and observations. Although we do not assume initial mass segregation, we observe that the simulated massive clusters show a shallower slope of the mass function ($\Gamma \sim -1.3$) in the cluster center compared to that of the entire cluster ($\Gamma \sim -1$). These values are consistent with those of some young massive clusters in the Milky Way such as Westerlund 1 and Arches.

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BANYAN. V. A Systematic All-Sky Survey for New Very Late-Type Low-Mass Stars and Brown Dwarfs in Nearby Young Moving Groups

Jonathan Gagné¹, David Lafrenière¹, René Doyon¹, Lison Malo²¹, Étienne Artigau¹

¹ Département de Physique, Université de Montréal, C.P. 6128 Succ. Centre-ville, Montréal, Qc H3C 3J7, Canada
² Canada-France-Hawaii Telescope, 65-1238 Mamalahoa Hwy, Kamuela, HI 96743, USA

E-mail contact: jonathan.gagne at astro.umontreal.ca

We present the BANYAN All-Sky Survey (BASS) catalog, consisting of 228 new late-type (M4-L6) candidate members of nearby young moving groups (YMGs) with an expected false-positive rate of ~13%. This sample includes 79 new candidate young brown dwarfs and 22 planetary-mass objects. These candidates were identified through the first systematic all-sky survey for late-type low-mass stars and brown dwarfs in YMGs. We cross-matched the 2MASS and ALLWISE catalogs outside of the galactic plane to build a sample of 98 970 potential $\geq$M5 dwarfs in the solar neighborhood and calculated their proper motions with typical precisions of 5–15 mas yr$^{-1}$. We selected highly probable candidate members of several YMGs from this sample using the Bayesian Analysis for Nearby Young Associations II tool (BANYAN II). We used the most probable statistical distances inferred from BANYAN II to estimate the spectral type and mass of these candidate YMG members. We used this unique sample to show tentative signs of mass segregation in the AB Doradus moving group and the Tucana-Horologium and Columba associations. The BASS sample has already been successful in identifying several new young brown dwarfs in earlier publications, and will be of great interest in studying the initial mass function of YMGs and for the search of exoplanets by direct imaging; the input sample of potential close-by $\geq$M5 dwarfs will be useful to study the kinematics of low-mass stars and brown dwarfs and search for new proper motion pairs.

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The dense gas mass fraction in the W51 cloud and its protoclusters

Adam Ginsburg¹, John Bally², Cara Battersby³, Allison Youngblood², Jeremy Darling², Erik Rosolowsky⁴, Héctor Arce⁵, Mayra E. Lebrón Santos⁶

¹European Southern Observatory, Karl-Schwarzschild-Strasse 2, D-85748 Garching bei München, Germany
²CASA, University of Colorado, 389-UCB, Boulder, CO 80309
³Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
⁴University of Alberta, Department of Physics, 4-181 CCIS, Edmonton AB T6G 2E1 Canada
⁵Department of Astronomy, Yale University, P.O. Box 208101, New Haven, CT 06520-8101 USA

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Context: The density structure of molecular clouds determines how they will evolve. Aims: To map the velocity-resolved density structure of the most vigorously star-forming molecular cloud in the Galactic disk, the W51 Giant Molecular Cloud.

Methods: We present new 2 cm and 6 cm maps of H$_2$CO, radio recombination lines, and the radio continuum in the W51 star forming complex acquired with Arecibo and the Green Bank Telescope at ~ 50 arcsec resolution. We use H$_2$CO absorption to determine the relative line-of-sight positions of molecular and ionized gas. We measure gas densities using the H$_2$CO densitometer, including continuous measurements of the dense gas mass fraction (DGMF) over the range 10$^4$ cm$^{-3}$ < n(H$_2$) < 10$^6$ cm$^{-3}$ - this is the first time a dense gas mass fraction has been measured over a range of densities with a single data set.

Results: The DGMF in W51 A is high, f > 70% above n > 10$^4$ cm$^{-3}$, while it is low, f < 20%, in W51 B. We did not detect any H$_2$CO emission throughout the W51 GMC; all gas dense enough to emit under normal conditions is in front of bright continuum sources and therefore is seen in absorption instead. The data set has been made public at http://dx.doi.org/10.7910/DVN/26818.

Conclusions: (1) The dense gas fraction in the W51 A and B clouds shows that W51 A will continue to form stars vigorously, while star formation has mostly ended in W51 B. The lack of dense, star-forming gas around W51 C indicates that collect-and-collapse is not acting or is inefficient in W51. (2) Ongoing high-mass star formation is correlated with n > 1 x 10$^5$ cm$^{-3}$ gas. Gas with n > 10$^4$ cm$^{-3}$ is weakly correlated with low and moderate mass star formation, but does not strongly correlate with high-mass star formation. (3) The nondetection of H$_2$CO emission implies that the emission detected in other galaxies, e.g., Arp 220, comes from high-density gas that is not directly affiliated with already-formed massive stars. Either the non-star-forming ISM of these galaxies is very dense, implying the star formation density threshold is higher, or HII regions have their emission suppressed.

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Hot Ammonia around Young O-type Stars.
I. JVLA imaging of Ammonia (6,6) to (14,14) in NGC7538 IRS1

Ciriaco Goddi$^1$, Qizhou Zhang$^2$ and Luca Moscadelli$^3$

$^1$ Joint Institute for VLBI in Europe, Postbox 2, 7990 AA Dwingeloo, The Netherlands
$^2$ Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
$^3$ INAF, Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy

E-mail contact: c.goddi at ru.astro.nl

To constrain theoretical models of high-mass star formation, observational signatures of mass accretion in O-type forming stars are desirable. Using the JVLA, we have mapped the hot and dense molecular gas in the hot core NGC7538 IRS1, with 0$''$2 angular resolution, in seven metastable (J=K) inversion transitions of ammonia: (J,K)=(6,6), (7,7), (9,9), (10,10), (12,12), (13,13), and (14,14). These lines arise from energy levels between ~400 K and ~1950 K above the ground state, and are observed in absorption against the HC-HII region associated with NGC7538 IRS1. With a 500 AU linear resolution, we resolve the elongated North-South ammonia structure into two compact components: the main core and a southernmost component. Previous observations of the radio continuum with a 0$''$08 (or 200 AU) resolution, resolved the compact core in two (northern and southern) components. These features correspond to a triple system of high-mass YSOs IRS1a, IRS1b, and IRS1c identified with VLBI measurements of methanol masers. The velocity maps of the compact core show a clear velocity gradient in all lines, which is indicative of rotation in a (circum)binary envelope, containing ~40 $M_\odot$ (dynamical mass). In addition, we derived physical conditions of the molecular gas: rotational temperatures ~280 K, ammonia column densities ~1.4 - 2.5 x 10$^{19}$ cm$^{-2}$, H$_2$ volume densities ~3.5 - 6.2 x 10$^{10}$ cm$^{-3}$, and a total gas mass in the range of 19-34 $M_\odot$, for the main core. We conclude that NGC7538 IRS1 is the densest hot molecular core known, containing a rotating envelope which hosts a multiple system of high-mass YSOs, possibly surrounded by accretion disks (as traced by methanol masers). Future JVLA observations in the A-configuration are needed to resolve the binary system in the core and may allow to study the gas kinematics in the accretion disks associated with individual binary members.
Hot Ammonia around Young O-type Stars.
II. JVLA imaging of highly-excited metastable ammonia masers in W51-North

Ciriaco Goddi¹, Christian Henkel², Qizhou Zhang³, Luis Zapata⁴ and Thomas L. Wilson⁵

¹ Joint Institute for VLBI in Europe, Postbox 2, 7990 AA Dwingeloo, The Netherlands
² Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
³ Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138
⁴ Centro de Radioastronomía y Astrofísica, UNAM, Morelia, Michoacán, México, C.P. 58089
⁵ US Naval Research Laboratory, Code 7213, Washington, DC 20375, USA

E-mail contact: c.goddi at ru.astro.nl

We have used the JVLA at the 1 cm band to map five highly-excited metastable inversion transitions of ammonia, (J,K)=(6,6), (7,7), (9,9), (10,10), and (13,13), in W51 IRS2 with ∼0″2 angular resolution. We present detections of both thermal (extended) ammonia emission in the five inversion lines, with rotational states ranging in energy from about 400 to 1700 K, and point-like ammonia maser emission in the (6,6), (7,7), and (9,9) lines. The thermal ammonia emits around a velocity of 60 km s⁻¹, near the cloud’s systemic velocity, is elongated in the east-west direction across 4 arcsec, and is confined by the HII regions W51d, W51d1, and W51d2. The ammonia masers are observed in the eastern tip of the dense clump traced by thermal ammonia, offset by 0″65 to the East from its emission peak, and have a peak velocity at 47.5 km s⁻¹. No maser components are detected near the systemic velocity. The ammonia masers are separated by 0″65 (3500 AU) from the (rare) vibrationally-excited SiO masers, excited by the deeply-embedded YSO W51-North. This excludes that the two maser species are excited by the same object. Interestingly, the ammonia masers originate at the same sky position as a peak in a submm line of SO₂ imaged with the SMA, tracing a face-on circumstellar disk/ring around W51-North. In addition, the thermal emission from the most highly excited ammonia lines, (10,10) and (13,13), shows two main condensations, the dominant one towards W51-North with the SiO/H₂O masers, and a weaker peak at the ammonia maser position. We propose a scenario where the ring seen in SO₂ emission is a circumbinary disk surrounding (at least) two high-mass YSOs, W51-North (exciting the SiO masers) and a nearby companion (exciting the ammonia masers), separated by 3500 AU. This finding indicates a physical connection (in a binary) between the two rare SiO and NH₃ maser species.

The density structure of the L1157 molecular outflow

A.I. Gómez-Ruiz¹*, C. Codella¹, B. Lefloch²,³, M. Benedettini⁴, G. Busquet⁵,⁴, C. Ceccarelli²,³, B. Nisini⁵, L. Podio¹, S. Viti⁷

¹ INAF, Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy
* Current address: Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE), Luis Enrique Erro No.1, C.P. 72840, Tonantzintla, Puebla, Mexico
² Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France
³ CNRS, IPAG, F-38000 Grenoble, France
⁴ INAF, Istituto di Astrofisica e Planetologia Spaziali, via Fosso del Cavaliere 100, 00133, Roma, Italy
⁵ Instituto de Astrofísica de Andalucía, CSIC, Glorieta de la Astronomía s/n, E-18008 Granada, Spain
⁶ INAF, Osservatorio Astronomico di Roma, via di Frascati 33, 00040, Monte Porzio Catone, Italy
⁷ Department of Physics and Astronomy, University College London, London, UK

E-mail contact: aigomez at inaoep.mx

We present a multiline CS survey towards the brightest bow-shock B1 in the prototypical chemically active protostellar outflow L1157. We made use of (sub-)mm data obtained in the framework of the Chemical HErschel Surveys of Star forming regions (CHESS) and Astrochemical Surveys at IRAM (ASAI) key science programs. We detected ¹²C³²S, ¹²C³⁴S, ¹³C³²S, and ¹²C³⁵S emissions, for a total of 18 transitions, with Eₚ up to ~180 K. The unprecedented sensitivity
of the survey allows us to carefully analyser the line profiles, revealing high-velocity emission, up to 20 km s^{-1} with respect to the systemic. The profiles can be well fitted by a combination of two exponential laws that are remarkably similar to what previously found using CO. These components have been related to the cavity walls produced by the ~2000 yr B1 shock and the older (~4000 yr) B2 shock, respectively. The combination of low- and high-excitation CS emission was used to properly sample the different physical components expected in a shocked region. Our CS observations show that this molecule is highlighting the dense, n(H₂) = 1–5 × 10^5 cm⁻³, cavity walls produced by the episodic outflow in L1157. In addition, the highest excitation (E_u ≥ 130 K) CS lines provide us with the signature of denser (1–5 × 10^5 cm⁻³) gas, associated with a molecular reformation zone of a dissociative J-type shock, which is expected to arise where the precessing jet impacting the molecular cavities. The CS fractional abundance increases up to ~10^{-7} in all the kinematical components. This value is consistent with what previously found for prototypical protostars and it is in agreement with the prediction of the abundances obtained via the chemical code Astrochem.

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The theory of globulettes: candidate precursors of brown dwarfs and free floating planets in H II regions
Thomas J. Haworth¹, Stefano Facchini¹ and Cathie J. Clarke¹

¹ Institute of Astronomy, Madingley Road, Cambridge, CB3 0HA, UK
E-mail contact: thaworth at ast.cam.ac.uk

Large numbers of small opaque dust clouds - termed ‘globulettes’ by Gahm et al - have been observed in the H II regions surrounding young stellar clusters. With masses typically in the planetary (or low mass brown dwarf) regime, these objects are so numerous in some regions (e.g. the Rosette) that, if only a small fraction of them could ultimately collapse, then they would be a very significant source of free floating planets. Here we review the properties of globulettes and present a theoretical framework for their structure and evolution. We demonstrate that their interior structure is well described by a pressure confined isothermal Bonnor-Ebert sphere and that the observed mass-radius relation (mass approximately proportional to the radius squared) is a systematic consequence of a column density threshold below which components of the globulette are not identified. We also find that globulettes with this interior structure are very stable against collapse within H II regions. We follow Gahm et al in assuming that globulettes are detached from the tips of pillars protruding in from the swept up shell that borders the expanding H II region and produce a model for their dynamics, finding that globulettes will eventually impact the shell. We derive an expression for the time it takes to do so and show that dissipation of energy via dust cooling allows all globulettes to survive this encounter and escape into the wider ISM. Once there the ambient pressure drops and they disperse on timescales around 30–300 kyr and should be observable using ALMA out to distances of order a parsec. Since we find that globulettes are stable, the only route via which they might still form brown dwarfs or planets is during their collision with the shell or some other violent perturbative event.

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Collisions of small ice particles under microgravity conditions
C. R. Hill¹, D. D. Heißelmann²,³, J. Blum² and H. J. Fraser¹

¹ The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK
² Technische Universität Braunschweig, Institut für Geophysik und extraterrestrische Physik, Mendelssohnstraße 3, 38106 Braunschweig, Germany
³ International Max-Planck Research School, Max-Planck Institute of Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany
E-mail contact: catherine.hill at open.ac.uk

Planetisimals are thought to be formed from the solid material of a protoplanetary disk by a process of dust aggregation. It is not known how growth proceeds to kilometre sizes, but it has been proposed that water ice beyond the snowline might affect this process. To better understand collisional processes in protoplanetary disks leading to planet
formation, the individual low velocity collisions of small ice particles were investigated. The particles were collided under microgravity conditions on a parabolic flight campaign using a purpose-built, cryogenically cooled experimental setup. The setup was capable of colliding pairs of small ice particles (between 4.7 and 10.8 mm in diameter) together at relative collision velocities of between 0.27 and 0.51 m/sec at temperatures between 131 and 160 K. Two types of ice particle were used: ice spheres and irregularly shaped ice fragments. Bouncing was observed in the majority of cases with a few cases of fragmentation. A full range of normalised impact parameters \( b/R = 0.0-1.0 \) was realised with this apparatus. Coefficients of restitution were evenly spread between 0.08 and 0.65 with an average value of 0.36, leading to a minimum of 58\% of translational energy being lost in the collision. The range of coefficients of restitution is attributed to the surface roughness of the particles used in the study. Analysis of particle rotation shows that up to 17\% of the energy of the particles before the collision was converted into rotational energy. Temperature did not affect the coefficients of restitution over the range studied.

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Chondrule destruction in nebular shocks
Emmanuel Jacquet\(^1\) and Christopher Thompson\(^1\)
\(^1\) Canadian Institute for Theoretical Astrophysics, University of Toronto, 60 St George Street, Toronto, ON, M5S 3H8, Canada
E-mail contact: ejacquet at mnhn.fr

Chondrules are millimeter-sized silicate spherules ubiquitous in primitive meteorites, but whose origin remains mysterious. One of the main proposed mechanisms for producing them is melting of solids in shock waves in the gaseous protoplanetary disk. However, evidence is mounting that chondrule-forming regions were enriched in solids well above solar abundances. Given the high velocities involved in shock models destructive collisions would be expected between differently sized grains after passage of the shock front as a result of differential drag. We investigate the probability and outcome of collisions of particles behind a 1D shock using analytic methods as well as a full integration of the coupled mass, momentum, energy and radiation equations. Destruction of protochondrules seems unavoidable for solid/gas ratios \( \epsilon \gtrsim 0.1 \), and possibly even for solar abundances because of “sandblasting” by finer dust. A flow with \( \epsilon \gtrsim 10 \) requires much smaller shock velocities (\( \sim 2 \) vs 8 km s\(^{-1}\)) in order to achieve chondrule-melting temperatures, and radiation trapping allows slow cooling of the shocked fragments. Initial destruction would still be extensive; although re-assembly of mm-sized particles would naturally occur by grain sticking afterward, the compositional heterogeneity of chondrules may be difficult to reproduce. We finally note that solids passing through small-scale bow shocks around few-km-sized planetesimals might experience partial melting and yet escape fragmentation.

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The Structural Evolution of Forming and Early Stage Star Clusters
Karl O. Jaehnig\(^1\), Nicola Da Rio\(^1\) and Jonathan C. Tan\(^{1,2}\)
\(^1\) Department of Astronomy, University of Florida, USA
\(^2\) Department of Physics, University of Florida, USA
E-mail contact: ndario at ufl.edu

We study the degree of angular substructure in the stellar position distribution of young members of Galactic star-forming regions, looking for correlations with distance from cluster center, surface number density of stars, and local dynamical age. To this end we adopt the catalog of members in 18 young (\( \sim 1–3 \) Myr) clusters from the Massive Young Star-Forming Complex Study in Infrared and X-ray (MYStIX) Survey and the statistical analysis of the Angular Dispersion Parameter, \( \delta_{\text{ADP}} \). We find statistically significant correlation between \( \delta_{\text{ADP}} \) and physical projected distance from the center of the clusters, with the centers appearing smoother than the outskirts, consistent with more rapid dynamical processing on local dynamical, free-fall or orbital timescales. Similarly, smoother distributions are seen in regions of higher surface density, or older dynamical ages. These results indicate that dynamical processing that erases substructure is already well-advanced in young, sometimes still-forming, clusters. Such observations of the dissipation
of substructure have the potential to constrain theoretical models of the dynamical evolution of young and forming clusters

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Mass and period limits on the ringed companion transiting the young star J1407


1 Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA Leiden, the Netherlands
2 LESIA, CNRS/UMR-8109, Observatoire de Paris, UPMC, Université Paris Diderot, 5 place Jules Janssen, 92195 Meudon, France
3 Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA
4 Kavli Institute for Astrophysics & Space Research, Massachusetts Institute of Technology, Cambridge, MA, USA
5 Observatoire Astronomique de l’Université de Genève, Chemin des Maillettes, 51, CH-1290 Sauverny, Switzerland
6 Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627-0171, USA
7 Research School of Astronomy and Astrophysics, Mt Stromlo Observatory, Cotter Rd, Weston ACT 2611, Australia
8 Center for Backyard Astrophysics (Antwerp), American Association of Variable Star Observers (AAVSO), Vereniging Voor Sterrenkunde (VVS), Andromeda Observatory, Oude Blikken 12, 2400 Mol, Belgium
9 Department of Physics and Astronomy, University of North Carolina at Chapel Hill, Campus Box 3255, Chapel Hill, NC 27599, USA

E-mail contact: kenworthy at strw.leidenuniv.nl

The young (~16 Myr) pre-main-sequence star in Sco-Cen 1SWASP J140747.93−394542.6, hereafter referred to as J1407, underwent a deep eclipse in 2007 April, bracketed by several shallower eclipses in the surrounding 54 d. This has been interpreted as the first detection of an eclipsing ring system circling a substellar object (dubbed J1407b). We report on a search for this companion with Sparse Aperture Mask imaging and direct imaging with both the UT4 VLT and Keck telescopes. Radial velocity measurements of J1407 provide additional constraints on J1407b and on short period companions to the central star. Follow-up photometric monitoring using the PROMPT-4 and ROAD observatories during 2012–2014 has not yielded any additional eclipses. Large regions of mass-period space are ruled out for the companion. For circular orbits the companion period is constrained to the range 3.5–13.8 yr (a ∼ 2.2–5.6 AU), and masses greater than 80 M\textsubscript{Jup} are ruled out at 3σ significance over these periods. The complex ring system appears to occupy more than 0.15 of its Hill radius, much larger than its Roche radius and suggesting a ring structure in transition. Further, we demonstrate that the radial velocity of J1407 is consistent with membership in the Upper Cen-Lup subgroup of the Sco-Cen association, and constraints on the rotation period and projected rotational velocity of J1407 are consistent with a stellar inclination of 68°±10°.

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New Candidate Eruptive Young Stars in Lynds 1340

M. Kun1, D. Apai2, J. O’Linger-Luscusk3, A. Moór1, B. Stecklum4, E. Szegedi-Elek1 and G. Wolf-Chase5,6

1 Konkoly Observatory, H-1121 Budapest, Konkoly Thege út 15-17, Hungary
2 Steward Observatory, 933 N. Cherry Av. Tucson, AZ, USA
3 On leave from California Institute of Technology, 1200 E California Ave, Pasadena, CA 91125, USA
4 Thüringer Landessternwarte Tautenburg, Sternwarte 5, 07778, Tautenburg, Germany
5 Astronomy Department, Adler Planetarium, 1300 S. Lake Shore Drive, Chicago, IL 60605, USA
6 Dept. of Astronomy & Astrophysics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA

E-mail contact: kun at konkoly.hu

We report on the discovery of three candidate eruptive young stars, found during our comprehensive multi-wavelength study of the young stellar population of the dark cloud L1340. These stars are as follows. (1) IRAS 02224+7227
(2MASS 02270555+7241167, HH 487 S) exhibited FUor-like spectrum in our low-resolution optical spectra. The available photometric data restrict its luminosity to $23\, L_\odot < L_{\text{bol}} < 59\, L_\odot$. (2) 2MASS 02263797+7304575, identified as a classical T Tauri star during our H$\alpha$ survey, exhibited an EXor type brightening in 2005 November, at the time of the SDSS observations of the region. (3) 2MASS 02325605+7246055, a low-mass embedded young star, associated with a fan-shaped infrared nebula, underwent an outburst between the DSS1 and DSS2 surveys, leading to the appearance of a faint optical nebula. Our $[S\, II]$ and H$\alpha$ images, as well as the Spitzer IRAC 4.5-micron images revealed Herbig–Haro objects associated with this star. Our results suggest that amplitudes and time scales of outbursts do not necessarily correlate with the evolutionary stage of the stars.

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Near-Infrared Circular Polarization Survey in Star-Forming Regions: Correlations and Trends
Jungmi Kwon$^{1,2}$, Motohide Tamura$^{1,2}$, James H. Hough$^3$, Nobuhiko Kusakabe$^2$, Tetsuya Nagata$^4$, Yasushi Nakajima$^5$, Phil W. Lucas$^3$, Takahiro Nagayama$^6$ and Ryo Kandori$^2$

$^1$ Department of Astronomy, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
$^2$ National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
$^3$ Centre for Astrophysics Research, University of Hertfordshire, College Lane, Hatfield AL10 9AB, UK
$^4$ Department of Astronomy, Kyoto University, Kyoto 606-8502, Japan
$^5$ Center of Information and Communication Technology, Hitotsubashi University, 2-1 Naka, Kunitachi, Tokyo 186-8601, Japan
$^6$ Department of Astrophysics, Kagoshima University, 1-21-35 Korimoto, Kagoshima 890-0065, Japan

E-mail contact: jungmi.kwon at astron.s.u-tokyo.ac.jp

We have conducted a systematic near-infrared circular polarization (CP) survey in star-forming regions, covering high-mass, intermediate-mass, and low-mass young stellar objects. All the observations were made using the SIRPOL imaging polarimeter on the Infrared Survey Facility 1.4 m telescope at the South African Astronomical Observatory. We present the polarization properties of ten sub-regions in six star-forming regions. The polarization patterns, extents, and maximum degrees of linear and circular polarizations are used to determine the prevalence and origin of CP in the star-forming regions. Our results show that the CP pattern is quadrupolar in general, the CP regions are extensive, up to 0.65 pc, the CP degrees are high, up to 20 percent, and the CP degrees decrease systematically from high- to low-mass young stellar objects. The results are consistent with dichroic extinction mechanisms generating the high degrees of CP in star forming regions.

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CARMA Large Area Star Formation Survey: Structure and Kinematics of Dense Gas in Serpens Main
Katherine I. Lee$^{1,2}$, Manuel Fernández-Lopez$^{2,3}$, Shaye Storm$^1$, Leslie W. Looney$^2$, Lee G. Mundy$^1$, Dominique Segura-Cox$^2$, Peter Teuben$^1$, Erik Rosolowsky$^{4,5}$, Héctor G. Arce$^6$, Eve C. Ostriker$^7$, Yancy L. Shirley$^8$, Woojin Kwon$^9$, Jens Kauffmann$^{10}$, John J. Tobin$^{11}$, Adele L. Plunkett$^6$, Marc W. Pound$^1$, Demerese M. Salter$^1$, N.H. Volgenau$^{12,13}$, Che-Yu Chen$^1$, Konstantinos Tassis$^{13,14}$, Andrea Isella$^{12}$, Richard M. Crutcher$^2$, Charles F. Gammie$^2$, Leonardo Testi$^{16}$

$^1$ Department of Astronomy, University of Maryland, College Park, MD 20742, USA
$^2$ Department of Astronomy, University of Illinois, Urbana-Champaign, IL 61801, USA
$^3$ Instituto Argentino de Radioastronomía, CCT-La Plata (CONICET), C.C.5, 1894, Villa Elisa, Argentina
$^4$ University of British Columbia, Okanagan Campus, Departments of Physics and Statistics, 3333 University Way, Kelowna BC V1V 1V7, Canada
$^5$ University of Alberta, Department of Physics, 4-181 CCIS, Edmonton AB T6G 2E1, Canada
We present observations of \( \text{N}_2\text{H}^+ (1-0), \text{HCO}^+ (1-0), \) and \( \text{HCN} (1-0) \) toward the Serpens Main molecular cloud from the CARMA Large Area Star Formation Survey (CLASSy). We mapped 150 square arcminutes of Serpens Main with an angular resolution of 7″. The gas emission is concentrated in two subclusters (the NW and SE subclusters). The SE subcluster has more prominent filamentary structures and more complicated kinematics compared to the NW subcluster. The majority of gas in the two subclusters has subsonic to sonic velocity dispersions. We applied a dendrogram technique with \( \text{N}_2\text{H}^+ (1-0) \) to study the gas structures; the SE subcluster has a higher degree of hierarchy than the NW subcluster. Combining the dendrogram and line fitting analyses reveals two distinct relations: a flat relation between nonthermal velocity dispersion and size, and a positive correlation between variation in velocity centroids and size. The two relations imply a characteristic depth of 0.15 pc for the cloud. Furthermore, we have identified six filaments in the SE subcluster. These filaments have lengths of 0.2 pc and widths of 0.03 pc, which is smaller than a characteristic width of 0.1 pc suggested by Herschel observations. The filaments can be classified into two types based on their properties. The first type, located in the northeast of the SE subcluster, has larger velocity gradients, smaller masses, and nearly critical mass-per-unit-length ratios. The other type, located in the southwest of the SE subcluster, has the opposite properties. Several YSOs are formed along two filaments which have supercritical mass per unit length ratios, while filaments with nearly critical mass-per-unit-length ratios are not associated with YSOs, suggesting that stars are formed on gravitationally unstable filaments.

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Hyperfine excitation of \( \text{N}_2\text{H}^+ \) by \( \text{H}_2 \): Toward a revision of \( \text{N}_2\text{H}^+ \) abundance in cold molecular clouds

Francois Lique\(^{1,4} \), Fabien Daniel\(^{2} \), Laurent Pagani\(^{3} \) and Nicole Feautrier\(^{4} \)

\(^{1} \)LOMC - UMR 6294, CNRS-Université du Havre, 25 rue Philippe Lebon, BP 1123, 76 063 Le Havre cedex, France
\(^{2} \)IPAG, Observatoire de Grenoble, Université Joseph Fourier, CNRS UMR5571, B.P. 53, 38041 Grenoble Cedex 09, France
\(^{3} \)LERMA and UMR 8112, CNRS, Observatoire de Paris, 61, Av. de l’Observatoire, 75014 Paris, France
\(^{4} \)LERMA and UMR 8112, CNRS- Observatoire de Paris-Meudon, 5 Place Jules Janssen, 92195 Meudon Cedex, France

E-mail contact: francois.lique at univ-lehavre.fr

The modelling of emission spectra of molecules seen in interstellar clouds requires the knowledge of collisional rate coefficients. Among the commonly observed species, \( \text{N}_2\text{H}^+ \) is of particular interest since it was shown to be a good probe of the physical conditions of cold molecular clouds. Thus, we have calculated hyperfine–structure resolved excitation rate coefficients of \( \text{N}_2\text{H}^+(X^1\Sigma^+) \) by \( \text{H}_2(j=0) \), the most abundant collisional partner in the cold interstellar medium. The calculations are based on a new potential energy surface, obtained from highly correlated \( \text{ab} \) \text{initio} calculations. State-to-state rate coefficients between the first hyperfine levels were calculated, for temperatures ranging from 5 K to 70 K. By comparison with previously published \( \text{N}_2\text{H}^+–\text{He} \) rate coefficients, we found significant differences which cannot be reproduced by a simple scaling relationship. As a first application, we also performed radiative transfer calculations, for physical conditions typical of cold molecular clouds. We found that the simulated line intensities significantly increase when using the new \( \text{H}_2 \) rate coefficients, by comparison with the predictions based on the \( \text{He} \)
rate coefficients. In particular, we revisited the modelling of the $N_2H^+$ emission in the LDN 183 core, using the new collisional data, and found that all three of the density, gas kinetic temperature and $N_2H^+$ abundance had to be revised.

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Migration and Growth of Protoplanetary Embryos II: Emergence of Proto-Gas-Giants Cores versus Super Earths’ Progenitor

Beibei Liu$^{1,2}$, Xiaojia Zhang$^3$, Douglas N.C. Lin$^{2,3,4}$, and Sverre J. Aarseth$^5$

1 Department of Astronomy & Astrophysics, Peking University, Beijing, 100871, China
2 Kavli Institute for Astronomy & Astrophysics, Peking University, Beijing, 100871, China
3 Department of Astronomy and Astrophysics, University of California, Santa Cruz, CA 95064, USA
4 Institute for Advanced Studies, Tsinghua University, Beijing, 100086, Beijing, China
5 Institute of Astronomy, Cambridge University, Cambridge, UK

E-mail contact: bbliu1208 at gmail.com

Nearly 15–20 of solar type stars contain one or more gas giant planet. According to the core-accretion scenario, the acquisition of their gaseous envelope must be preceded by the formation of super-critical cores with masses ten times or larger than that of the Earth. It is natural to link the formation probability of gas giant planets with the supply of gas and solid in their natal disks. However, a much richer population of super Earths suggests that 1) there is no shortage of planetary building-block material, 2) gas giants’ growth barrier is probably associated with whether they can merge into super-critical cores, and 3) super Earths are probably failed cores which did not attain sufficient mass to initiate efficient accretion of gas before it is severely depleted. Here we construct a model based on the hypothesis that protoplanetary embryos migrated extensively before they were assembled into bona fide planets. We construct a Hermite-Embryo code based on a unified viscous-irradiation disk model and a prescription for the embryo-disk tidal interaction. This code is used to simulate 1) the convergent migration of embryos, and 2) their close encounters and coagulation. Around the progenitors of solar-type stars, the progenitor super-critical-mass cores of gas giant planets primarily form in protostellar disks with relatively high ($\gtrsim 10^{-7} \, M_\odot \, \text{yr}^{-1}$) mass accretion rates whereas systems of super Earths (failed cores) are more likely to emerge out of natal disks with modest mass accretion rates, due to the mean motion resonance barrier and retention efficiency.

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Very Large Array and Jansky Very Large Array observations of the compact radio sources in M8

J.M. Masqué$^1$, S. Dzib$^2$ and L.F. Rodríguez$^{1,3}$

1 Centro de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Morelia 58089, México
2 Max-Plank-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
3 Astronomy Department, Faculty of Science, King Abdulaziz University, P.O. Box 80203, Jeddah 21589, Saudi Arabia

E-mail contact: j.masque at crya.unam.mx

We analyze high-resolution Very Large Array and Jansky Very Large Array continuum observations of the M8 region carried out at several epochs that span a period of 30 yr. Our maps reveal two compact sources. One is associated with Her 36 SE, a possible companion of the O7 luminous massive star Her 36, and the other is associated to G5.97-1.17, whose proplyd nature was previously established. With the analyzed data, we do not find significant time variability in any of these sources. The derived spectral index of $\geq 0.1$ for Her 36 SE, the marginal offset of the radio emission with the previous IR detection and the associated X-ray emission previously reported suggest the presence of an unresolved interaction region between the strong winds of Her 36 and Her 36 SE. This region would produce non-thermal contamination to the global wind emission of Her 36 flattening its spectral index. On the other hand, the emission of G5.97-1.17 can be also explained by a mixture of thermal and non-thermal emission components, with
different relative contribution of both emission mechanisms along the proplyd. We argue that the shock created by the photo-evaporation flow of the proplyd with the collimated stellar wind of Her 36 accelerates charged particles in G5.97-1.17 producing considerable synchrotron emission. On the contrary, an electron density enhancement at the southwest of G5.97-1.17 makes the thermal emission dominant over this region.

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Young open clusters in the galactic star forming region NGC 6357
Fabrizio Massi1, Andrea Giannetti2,5, Elisa Di Carlo3, Jan Brand2,5, Maria Teresa Beltrán1 and Gianni Marconi4
1 INAF - Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy
2 INAF - Istituto di Radioastronomia, via Gobetti 101, I-40129 Bologna, Italy
3 INAF - Osservatorio Astronomico di Collurania-Teramo, Via M. Maggini, I-64100 Teramo, Italy
4 ESO, Alónso de Córdova 3107, Vitacura, Santiago de Chile, Chile
5 Italian ALMA Regional Centre, via Gobetti 101, I-40129 Bologna, Italy
E-mail contact: fmassi at arcetri.astro.it

NGC 6357 is an active star forming region with very young massive open clusters. These clusters contain some of the most massive stars in the Galaxy and strongly interact with nearby giant molecular clouds. We study the young stellar populations of the region and of the open cluster Pismis 24, focusing on their relationship with the nearby giant molecular clouds. We seek evidence of triggered star formation “propagating” from the clusters. We used new deep JHKs photometry, along with unpublished deep IRAC/Spitzer mid-infrared photometry, complemented with optical HST/WFPC2 high spatial resolution photometry and X-ray Chandra observations, to constrain age, initial mass function, and star formation modes in progress. We carefully examine and discuss all sources of bias (saturation, confusion, different sensitivities, extinction). NGC 6357 hosts three large young stellar clusters, of which Pismis 24 is the most prominent. We found that Pismis 24 is a very young (∼1 − 3 Myr) open cluster with a Salpeter-like IMF and a few thousand members. A comparison between optical and infrared photometry indicates that the fraction of members with a near-infrared excess (i. e., with a circumstellar disk) is in the range 0.3 – 0.6, consistent with its photometrically derived age. We also find that Pismis 24 is likely subdivided into a few different subclusters, one of which contains almost all the massive members. There are indications of current star formation triggered by these massive stars, but clear age trends could not be derived (although the fraction of stars with a near-infrared excess does increase towards the HII region associated with the cluster). The gas out of which Pismis 24 formed must have been distributed in dense clumps within a cloud of less dense gas ∼ 1 pc in radius. Our findings provide some new insight into how young stellar populations and massive stars emerge, and evolve in the first few Myr after birth, from a giant molecular cloud complex.

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Protoplanetary disk masses from CO isotopologues line emission
Anna Miotello1,2, Simon Bruderer2 and Ewine F. van Dishoeck1,2
1 Leiden Observatory, Leiden University, Niels Bohrweg 2, NL-2333 CA Leiden, The Netherlands
2 Max-Planck-Institute für extraterrestrische Physik, Giessenbachstraße, D-85748 Garching, Germany
E-mail contact: miotello at strw.leidenuniv.nl

One of the methods for deriving disk masses relies on direct observations of the gas, whose bulk mass is in the outer cold (T < 30K) regions. This zone can be well traced by rotational lines of less abundant CO isotopologues such as 13CO, C18O and C17O, that probe the gas down to the midplane. The total CO gas mass is then obtained with the isotopologue ratios taken to be constant at the elemental isotope values found in the local ISM. This approach is however imprecise, because isotope selective processes are ignored. The aim of this work is an isotopologue selective treatment of CO isotopologues, in order to obtain a more accurate determination of disk masses. The isotope-selective photodissociation, the main process controlling the abundances of CO isotopologues in the CO-emissive layer, is
properly treated for the first time in a full disk model (DALI, Bruderer et al. 2012; Bruderer 2013). The chemistry, thermal balance, line and continuum radiative transfer are all considered together with a chemical network that treats $^{13}$CO, $^{18}$O, $^{17}$O, isotopes of all included atoms, and molecules, as independent species. Isotope selective processes lead to regions in the disk where the isotopologues abundance ratios e.g. of $^{18}$O/$^{12}$CO are considerably different from the elemental $^{18}$O/$^{16}$O ratio. The results of this work show that considering CO isotopologue ratios as constants can lead to an underestimate of disk masses by up to an order of magnitude or more if grains have grown to larger sizes. This may explain observed discrepancies in mass determinations from different tracers. The dependence of the various isotopologues emission on stellar and disk parameters is investigated, to set the framework for the analysis of ALMA data. Including CO isotope selective processes is crucial to determine the gas mass of the disk accurately (through ALMA observations) and thus to provide the amount of gas which may eventually form planets or change the dynamics of forming planetary systems.

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External Photoevaporation of the Solar Nebula: Jupiter’s Noble Gas Enrichments

Nikhil Monga¹ and Steven Desch¹

¹ School of Earth and Space Exploration, Arizona State University, PO Box 871404, Tempe, AZ 85287-1404

E-mail contact: nikhil.monga at asu.edu

We present a model explaining elemental enrichments in Jupiter’s atmosphere, particularly the noble gases Ar, Kr, and Xe. While He, Ne and O are depleted, seven other elements show similar enrichments (∼3 times solar, relative to H). Being volatile, Ar is difficult to fractionate from H2. We argue that external photoevaporation by far ultraviolet (FUV) radiation from nearby massive stars removed H2, He, and Ne from the solar nebula, but Ar and other species were retained because photoevaporation occurred at large heliocentric distances where temperatures were cold enough (<30 K) to trap them in amorphous water ice. As the solar nebula lost H it became relatively and uniformly enriched in other species. Our model improves on the similar model of Guillot & Hueso (2006). We recognize that cold temperatures alone do not trap volatiles; continuous water vapor production also is necessary. We demonstrate that FUV fluxes that photoevaporated the disk generated sufficient water vapor, in regions <30 K, to trap gas-phase species in amorphous water ice, in solar proportions. We find more efficient chemical fractionation in the outer disk: whereas the model of Guillot & Hueso (2006) predicts a factor of 3 enrichment when only <2% of the disk mass remains, we find the same enrichments when 30% of the disk mass remains. Finally, we predict the presence of ∼0.1 $M_\odot$ of water vapor in the outer solar nebula and in protoplanetary disks in H II regions.

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A stellar-mass-dependent drop in planet occurrence rates

Gijs D. Mulders¹, Ilaria Pascucci¹ and Daniel Apai¹²

¹ Lunar and Planetary Laboratory, The University of Arizona, Tucson, AZ, USA
² Department of Astronomy, The University of Arizona, Tucson, AZ, USA

E-mail contact: mulders at lpl.arizona.edu

The Kepler Spacecraft has discovered a large number of planets up to one-year periods and down to terrestrial sizes. While the majority of the target stars are main-sequence dwarfs of spectral type F, G, and K, Kepler covers stars with effective temperature as low as 2500 K, which corresponds to M stars. These cooler stars allow characterization of small planets near the habitable zone, yet it is not clear if this population is representative of that around FGK stars. In this paper, we calculate the occurrence of planets around stars of different spectral types as a function of planet radius and distance from the star, and show that they are significantly different from each other. We further identify two trends: First, the occurrence of Earth to Neptune-sized planets (1-4 Earth radii) is successively higher toward later spectral types at all orbital periods probed by Kepler; Planets around M stars occur twice as frequently as around G stars, and thrice as frequently as around F stars. Second, a drop in planet occurrence is evident at all spectral types inward of a 10 day orbital period, with a plateau further out. By assigning to each spectral type a
median stellar mass, we show that the distance from the star where this drop occurs is stellar mass dependent, and scales with semi-major axis as the cube root of stellar mass. By comparing different mechanisms of planet formation, trapping and destruction, we find that this scaling best matches the location of the pre-main-sequence co-rotation radius, indicating efficient trapping of migrating planets or planetary building blocks close to the star. These results demonstrate the stellar-mass dependence of the planet population, both in terms of occurrence rate and of orbital distribution. The prominent stellar-mass dependence of the inner boundary of the planet population shows that the formation or migration of planets is sensitive to the stellar parameters.

Hydrodynamics of Embedded Planets’ First Atmospheres. I. A Centrifugal Growth Barrier for 2D Flows

Chris W. Ormel1, Rolf Kuiper2, Ji-Ming Shi1,3

1 Astronomy Department, University of California, Berkeley, CA 94720, USA
2 Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
3 Department of Astrophysical Sciences, Princeton University, Princeton, NJ, USA

E-mail contact: ormel at astro.berkeley.edu

In the core accretion paradigm of planet formation, gas giants only form a massive atmosphere after their progenitors exceeded a threshold mass: the critical core mass. Most (exo)planets, being smaller and rock/ice-dominated, never crossed this line. Nevertheless, they were massive enough to attract substantial amounts of gas from the disc, while their atmospheres remained in pressure-equilibrium with the disc. Our goal is to characterise the hydrodynamical properties of the atmospheres of such embedded planets and their implication for their (long-term) evolution. In this paper – the first in series – we start to investigate the properties of an isothermal and inviscid flow past a small, embedded planet by conducting local, 2D hydrodynamical simulations. Using the PLUTO code we confirm that the flow is steady and bound. This steady outcome is most apparent for the log-polar grid (with the grid spacing proportional to the distance from the planet). For low-mass planets, Cartesian grids are somewhat less efficient as they have difficulty to follow the circular, large speeds in the deep atmosphere. Relating the amount of rotation to the gas fraction of the atmosphere, we find that more massive atmospheres rotate faster – a finding consistent with Kelvin’s circulation theorem. Rotation therefore limits the amount of gas that planets can acquire from the nebula. Dependent on the Toomre-Q parameter of the circumstellar disc, the planet’s atmosphere will reach Keplerian rotation before self-gravity starts to become important.

A Substellar-Mass Protostar and its Outflow of IRAS IRAS 15398−3359 revealed by Subarcsecond-resolution Observations of H2CO and CCH

Yoko Oya1, Nami Sakai1, Takeshi Sakai2, Yoshimasa Watanabe1, Tomoya Hirota3, Johan E. Lindberg4,5, Suzanne E. Bischop4,5, Jes K. Jrgensen4,5, Ewine F. van Dishoeck6,7 and Satoshi Yamamoto1

1 Department of Physics, The University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan
2 Department of Communication Engineering and Informatics, Graduate School of Informatics and Engineering, The University of Electro-Communications, Chofu-gaoka, Chofu, Tokyo 182-8585, Japan
3 National Astronomical Observatory of Japan, Osawa, Mitaka, Tokyo 181-8588, Japan
4 Center for Star and Planet Formation, Natural History Museum of Denmark, University of Copenhagen, steer Voldgade 5-7, DK-1350 Copenhagen K, Denmark
5 Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, DK-2100 Copenhagen, Denmark
6 Leiden Observatory, Leiden University, P.O. Box 9513, 2300-RA Leiden, The Netherland
7 Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse 1, D-85748 Garching, Germany

E-mail contact: oya at taurus.phys.s.u-tokyo.ac.jp

Sub-arcsecond (0.75") images of H2CO and CCH line emission have been obtained in the 0.8 mm band toward the
low-mass protostar IRAS 15398–3359 in the Lupus 1 cloud as one of the Cycle 0 projects of the Atacama Large Millimeter/Submillimeter Array. We have detected a compact component concentrated in the vicinity of the protostar and a well-collimated outflow cavity extending along the northeast-southwest axis. The inclination angle of the outflow is found to be about 20°, or almost edge-on, based on the kinematic structure of the outflow cavity. This is in contrast to previous suggestions of a more pole-on geometry. The centrally concentrated component is interpreted by use of a model of the infalling rotating envelope with the estimated inclination angle and the mass of the protostar is estimated to be less than 0.09 $M_\odot$. Higher spatial resolution data are needed to infer the presence of a rotationally supported disk for this source, hinted at by a weak high-velocity H$_2$CO emission associated with the protostar.

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CO gas inside the protoplanetary disk cavity in HD 142527: disk structure from ALMA

S. Perez$^{1,2}$, S. Casassus$^{1,2}$, F. Ménard$^{2,3,4}$, P. Roman$^{2,6}$, G. van der Plas$^{1,2}$, L. Cieza$^{2,5}$, C. Pinte$^{3,4}$, V. Christiaens$^{1,2}$, A.S. Hales$^{2,7}$

$^1$ Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile
$^2$ Millenium Nucleus “Protoplanetary Disks in ALMA Early Science,” Universidad de Chile, Casilla 36-D, Santiago, Chile
$^3$ UMI-FCA 3386, CNRS/INSU, Casilla 36-D, Santiago, Chile
$^4$ Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France
$^5$ CNRS, IPAG, F-38000 Grenoble, France
$^6$ Universidad Diego Portales, Facultad de Ingeniería, Av. Ejército 441, Santiago, Chile
$^7$ Center of Mathematical Modelling, Universidad de Chile

E-mail contact: sebastian.astrophysics at gmail.com

Inner cavities and annular gaps in circumstellar disks are possible signposts of giant planet formation. The young star HD 142527 hosts a massive protoplanetary disk with a large cavity that extends up to 140 AU from the central star, as seen in continuum images at infrared and millimeter wavelengths. Estimates of the survival of gas inside disk cavities are needed to discriminate between clearing scenarios. We present a spatially and spectrally resolved carbon monoxide isotopologue observations of the gas-rich disk HD 142527, in the $J = 2–1$ line of $^{12}$CO, $^{13}$CO and C$^{18}$O, obtained with the Atacama Large Millimeter Array (ALMA). We detect emission coming from inside the dust-depleted cavity in all three isotopologues. Based on our analysis of the gas in the dust cavity, the $^{12}$CO emission is optically thick, while $^{13}$CO and C$^{18}$O emission are both optically thin. The total mass of residual gas inside the cavity is about 1.5–2 $M_J$. We model the gas with an axisymmetric disk model. Our best fit model shows that the cavity radius is much smaller in CO than it is in millimeter continuum and scattered light observations, with a gas cavity that does not extend beyond 105 AU (at 3σ). The gap wall at its outer edge is diffuse and smooth in the gas distribution, while in dust continuum it is manifestly sharper. The inclination angle, as estimated from the high velocity channel maps, is $28°±0°5$, higher than in previous estimates, assuming a fixed central star mass of 2.2 $M_\odot$.

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Outward migration of Jupiter and Saturn in 3:2 or 2:1 resonance in radiative disks: implications for the Grand Tack and Nice models

Arnaud Pierens$^{1,2}$, Sean Raymond$^{1,2}$, David Nesvorny$^3$, and Alessandro Morbidelli$^4$

$^1$ Univ. Bordeaux, Laboratoire d’Astrophysique de Bordeaux, UMR 5804, F-33270, Floirac, France
$^2$ CNRS, Laboratoire d’Astrophysique de Bordeaux, UMR 5804, F-33270, Floirac, France
$^3$ Department of Space Studies, Southwest Research Institute, 1050 Walnut Street Suite 300, Boulder, CO 80302, USA
$^4$ University of Nice-Sophia Antipolis, CNRS, Observatoire de la côte d’Azur, Laboratoire Lagrange, BP4229, 06304 NICE Cedex 4, France

E-mail contact: arnaud.pierens at obs.u-bordeaux1.fr
Embedded in the gaseous protoplanetary disk, Jupiter and Saturn naturally become trapped in 3:2 resonance and migrate outward. This serves as the basis of the Grand Tack model. However, previous hydrodynamical simulations were restricted to isothermal disks, with moderate aspect ratio and viscosity. Here we simulate the orbital evolution of the gas giants in disks with viscous heating and radiative cooling. We find that Jupiter and Saturn migrate outward in 3:2 resonance in modest-mass \( M_{\text{disk}} \approx M_{\text{MMSN}} \), where MMSN is the “minimum-mass solar nebula”) disks with viscous stress parameter \( \alpha \) between \( 10^{-3} \) and \( 10^{-2} \). In disks with relatively low-mass \( M_{\text{disk}} \lesssim M_{\text{MMSN}} \), Jupiter and Saturn get captured in 2:1 resonance and can even migrate outward in low-viscosity disks \( (\alpha \lesssim 10^{-4}) \). Such disks have a very small aspect ratio \( (h \approx 0.02-0.03) \) that favors outward migration after capture in 2:1 resonance, as confirmed by isothermal runs which resulted in a similar outcome for \( h \approx 0.02 \) and \( \alpha \lesssim 10^{-4} \). We also performed N-body runs of the outer Solar System starting from the results of our hydrodynamical simulations and including 2–3 ice giants. After dispersal of the gaseous disk, a Nice model instability starting with Jupiter and Saturn in 2:1 resonance results in good Solar Systems analogs. We conclude that in a cold Solar Nebula, the 2:1 resonance between Jupiter and Saturn can lead to outward migration of the system, and this may represent an alternative scenario for the evolution of the Solar System.

Magnetic Fields in High-Mass Infrared Dark Clouds

T. Pillai1,2, J. Kauffmann1,2, J.C. Tan3, P.F. Goldsmith4, S.J. Carey5, K.M. Menten2

1 California Institute of Technology, Cahill Center for Astronomy and Astrophysics, Pasadena, CA 91125, USA
2 Max Planck Institut für Radioastronomie, Germany
3 University of Florida, USA
4 Jet Propulsion Laboratory, California Institute of Technology, USA
5 IPAC, California Institute of Technology, USA

E-mail contact: tpillai.astro at gmail.com

High-mass Stars are cosmic engines known to dominate the energetics in the Milky Way and other galaxies. However, their formation is still not well understood. Massive, cold, dense clouds, often appearing as Infrared Dark Clouds (IRDCs), are the nurseries of massive stars. No measurements of magnetic fields in IRDCs in a state prior to the onset of high-mass star formation (HMSF) have previously been available, and prevailing HMSF theories do not consider strong magnetic fields. Here, we report observations of magnetic fields in two of the most massive IRDCs in the Milky Way. We show that IRDCs G11.11−0.12 and G0.253+0.016 are strongly magnetized and that the strong magnetic field is as important as turbulence and gravity for HMSF. The main dense filament in G11.11−0.12 is perpendicular to the magnetic field, while the lower density filament merging onto the main filament is parallel to the magnetic field. The implied magnetic field is strong enough to suppress fragmentation sufficiently to allow HMSF. Other mechanisms reducing fragmentation, such as the entrapment of heating from young stars via high mass surface densities, are not required to facilitate HMSF.

Gas and dust structures in protoplanetary disks hosting multiple planets

P. Pinilla1, M. de Juan Ovelar2, S. Ataiee3, M. Benisty4, T. Birnstiel5, E.F. van Dishoeck1,6, M. Min7

1 Leiden Observatory, Leiden University, P.O. Box 9513, 2300RA Leiden, The Netherlands
2 Astrophysics Research Institute, Liverpool John Moores University,146 Brownlow Hill, Liverpool L3 5RF, UK
3 School of Astronomy, Institute for Research in Fundamental Sciences, Tehran, Iran
4 Laboratoire d’Astrophysique, Observatoire de Grenoble, CNRS/UJF UMR 5571, 414 rue de la Piscine, BP 53, 38041 Grenoble Cedex 9, France
5 Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
6 Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse 1, 85748, Garching, Germany
7 Astronomical Institute Anton Pannekoek, University of Amsterdam, PO Box 94249, 1090 GE Amsterdam, The
Transition disks have dust depleted inner regions and may represent an intermediate step of an on-going disk dispersal process, where planet formation is probably in progress. Recent millimetre observations of transition disks reveal radially and azimuthally asymmetric structures, where micron- and millimetre-sized dust particles may not spatially coexist. These properties can be the result of particle trapping and grain growth in pressure bumps originating from the disk interaction with a planetary companion. The multiple features observed in some transition disks such as SR 21 suggest the presence of more than one planet. We study the gas and dust distributions of a disk hosting two massive planets as function of different disk and dust parameters. Observational signatures such as the spectral energy distribution, sub-millimetre, and polarised images are simulated for the various parameters. We confirm that planets can lead to particle trapping, although for a disk with high viscosity ($\alpha_{\text{turb}} = 10^{-2}$), the planet should be more massive than 5 $M_{\text{Jup}}$ and dust fragmentation should occur with low efficiency ($\nu_f \sim 30 \, \text{m s}^{-1}$). This will lead to a ring-like feature as observed in transition disks in the millimetre. When trapping occurs, we find that a smooth distribution of micron sized grains throughout the disk, sometimes observed in scattered light, can only happen if the combination of planet mass and turbulence is such that small grains are not fully filtered out. A high disk viscosity ($\alpha_{\text{turb}} = 10^{-2}$) ensures a replenishment of the cavity in micron-sized dust, while for lower viscosity ($\alpha_{\text{turb}} = 10^{-3}$), the planet mass is constrained to be less than 5 $M_{\text{Jup}}$. In these cases, the gas distribution is likely to show low-amplitude azimuthal asymmetries caused by disk eccentricity rather than by long-lived vortices.

Kinematics of powerful jets from intermediate-mass protostars in the Carina nebula

Megan Reiter$^1$ and Nathan Smith$^1$

$^1$ Steward Observatory, University of Arizona, Tucson, AZ, 85721-0065, USA

E-mail contact: mreiter at as.arizona.edu

We present measurements of proper motions and radial velocities of four powerful Herbig-Haro (HH) jets in the Carina nebula: HH 666, HH 901, HH 902, and HH 1066. Two epochs of Hubble Space Telescope (HST) imaging separated by a time baseline of $\sim 4.4$ years provide proper motions that allow us to measure the transverse velocities of the jets, while ground-based spectra sample their Doppler velocities. Together these yield full three-dimensional space velocities. Aside from HH 666, their identification as outflows was previously inferred only from morphology in images. Proper motions now show decisively that these objects are indeed jets, and confirm that the intermediate-mass protostars identified as the candidate driving sources for HH 666 and HH 1066 are indeed the origin of these outflows. The appearance of two new knots in the HH 1066 jet suggest recent ($\sim 35$ yr) changes in the accretion rate, underscoring the variable nature of accretion and outflow in the formation of intermediate-mass stars. In fact, kinematics and mass-ejection histories for all the jets suggest highly episodic mass loss, and point toward pronounced accretion fluctuations. Overall, we measure velocities similar to those found for low-mass protostars. However, the HH jets in Carina have higher densities and are more massive than their low-mass counterparts. Coarse estimates suggest that the heavy jets of intermediate-mass protostars can compete with or even exceed inject $\sim 10$ or more times the cumulative momentum injection of lower-mass protostars.

Are turbulent spheres suitable initial conditions for star-forming clouds?

Ramon Rey-Raposo$^1$, Clare Dobbs$^1$ and Ana Duarte-Cabral$^1$

$^1$ University of Exeter, UK

E-mail contact: rrr at astro.ex.ac.uk

To date, most numerical simulations of molecular clouds, and star formation within them, assume a uniform density sphere or box with an imposed turbulent velocity field. In this work, we select molecular clouds from galactic scale
simulations as initial conditions, increase their resolution, and re-simulate them using the SPH code Gadget2. Our approach provides clouds with morphologies, internal structures, and kinematics that constitute more consistent and realistic initial conditions for simulations of star formation. We perform comparisons between molecular clouds derived from a galactic simulation, and spheres of turbulent gas of similar dimensions, mass and velocity dispersion. We focus on properties of the clouds such as their density, velocity structure and star formation rate. We find that the inherited velocity structure of the galactic clouds has a significant impact on the star formation rate and evolution of the cloud. Our results indicate that, although we can follow the time evolution of star formation in any simulated cloud, capturing the entire history is difficult as we ignore any star formation that might have occurred before initialisation. Overall, the turbulent spheres do not match the complexity of the galactic clouds.

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Very low-luminosity Class I/Flat outflow sources in sigma Orionis

B. Riaz1, M. Thompson1, E.T. Whelan2, N. Lodieu3,4

1 Centre for Astrophysics Research, Science & Technology Research Institute, University of Hertfordshire, Hatfield, AL10 9AB, UK
2 Institute für Astronomie und Astrophysik, Eberhard Karls University Tubingen, Sand 1, D-72076 Tübingen, Germany
3 Instituto de Astrofisica de Canarias, E-38206 La Laguna, Tenerife, Spain
4 Departamento de Astrofisica, Universidad de La Laguna, E-38206 La Laguna, Tenerife, Spain

E-mail contact: basriaz at astro.umd.edu

We present an optical through sub-millimetre multi-wavelength study of two very low-luminosity Class I/Flat systems, Mayrit 1701117 and Mayrit 1082188, in the σ Orionis cluster. We performed moderate resolution (R ~ 1000) optical (~0.4–0.9 μm) spectroscopy with the TWIN spectrograph at the Calar Alto 3.5-m telescope. The spectra for both sources show prominent emission in accretion- and outflow-associated lines. The mean accretion rate measured from multiple line diagnostics is 6.4×10^{-10} M⊙ yr^{-1} for Mayrit 1701117, and 2.5×10^{-10} M⊙ yr^{-1} for Mayrit 1082188. The outflow mass loss rates for the two systems are similar and estimated to be ~1 × 10^{-9} M⊙ yr^{-1}. The activity rates are within the range observed for low-mass Class I protostars. We obtained sub-millimetre continuum observations with the Submillimetre Common-User Bolometer Array (SCUBA-2) bolometer at the James Clerk Maxwell Telescope. Both objects are detected at a >5σ level in the SCUBA-2 850 μm band. The bolometric luminosity of the targets as measured from the observed spectral energy distribution over ~0.8–850 μm is 0.18±0.04 L⊙ for Mayrit 1701117, and 0.16±0.03 L⊙ for Mayrit 1082188, and is in the very low-mass range. The total dust+gas mass derived from sub-millimetre fluxes is ~36 M_Jup and ~22 M_Jup for Mayrit 1701117 and Mayrit 1082188, respectively. There is the possibility that some of the envelope material might be dissipated by the strong outflows driven by these sources, resulting in a final mass of the system close to or below the sub-stellar limit.

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On the Morphology and Chemical Composition of the HR 4796A Debris Disk

Timothy J. Rodigas1, Christopher C. Stark2, Alycia Weinberger1, John H. Debes3, Philip M. Hinz4, Laird Close4, Christine Chen3, Paul S. Smith4, Jared R. Males4, Andrew J. Skemer4, Alfio Puglisi5, Katherine B. Follette4, Katie Morzinski4, Ya-Lin Wu4, Runa Briguglio5, Simone Esposito5, Enrico Pinna5, Armando Riccardi5, Glenn Schneider4, Marco Xompero5

1 Department of Terrestrial Magnetism, Carnegie Institute of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015, USA
2 NASA Goddard Space Flight Center, Exoplanets & Stellar Astrophysics Laboratory, Code 667, Greenbelt, MD 20771
3 Space Telescope Science Institute, Baltimore, MD 21218, USA
4 Steward Observatory, The University of Arizona, 933 N. Cherry Ave., Tucson, AZ 85721, USA

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We present resolved images of the HR 4796A debris disk using the Magellan adaptive optics system paired with Clio-2 and VisAO. We detect the disk at 0.77 \( \mu \text{m} \), 0.91 \( \mu \text{m} \), 0.99 \( \mu \text{m} \), 2.15 \( \mu \text{m} \), 3.1 \( \mu \text{m} \), 3.3 \( \mu \text{m} \), and 3.8 \( \mu \text{m} \). We find that the deprojected center of the ring is offset from the star by 4.76\( \pm \)1.6 AU and that the deprojected eccentricity is 0.06\( \pm \)0.02, in general agreement with previous studies. We find that the average width of the ring is 14\( \pm \)3\%, also comparable to previous measurements. Such a narrow ring precludes the existence of shepherding planets more massive than \( \sim 4 \) \( M_J \), comparable to hot-start planets we could have detected beyond \( \sim 60 \) AU in projected separation. Combining our new scattered light data with archival HST/STIS and HST/NICMOS data at \( \sim 0.5-2 \) \( \mu \text{m} \), along with previously unpublished Spitzer/MIPS thermal emission data and all other literature thermal data, we set out to constrain the chemical composition of the dust grains. After testing 19 individual root compositions and more than 8,400 unique mixtures of these compositions, we find that good fits to the scattered light alone and thermal emission alone are discrepant, suggesting that caution should be exercised if fitting to only one or the other. When we fit to both the scattered light and thermal emission simultaneously, we find mediocre fits (reduced chi-square \( \sim 2 \)). In general, however, we find that silicates and organics are the most favored, and that water ice is usually not favored. These results suggest that the common constituents of both interstellar dust and solar system comets also may reside around HR 4796A, though improved modeling is necessary to place better constraints on the exact chemical composition of the dust.

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Weak and Compact Radio Emission in Early Massive Star Formation Regions: An Ionized Jet Toward G11.11-0.12P1

V. Rosero\(^1\), P. Hofner\(^1\), M. McCoy\(^1\), S. Kurtz\(^2\), K. M. Menten\(^3\), F. Wyrowski\(^3\), E. D. Araya\(^4\), L. Loinard\(^2\), C. Carrasco-González\(^2\), L. F. Rodríguez\(^2\), R. Cesaroni\(^5\) and S. P. Ellingsen\(^6\)

\(^1\) Physics Department, New Mexico Tech, 801 Leroy Pl., Socorro, NM 87801, USA
\(^2\) Centro de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Morelia 58090, México
\(^3\) Max-Planck-Institute für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
\(^4\) Physics Department, Western Illinois University, 1 University Circle, Macomb, IL 61455, USA
\(^5\) INAF, Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy
\(^6\) School of Physical Sciences, University of Tasmania, Private Bag 37, Hobart, Tasmania 7001, Australia

E-mail contact: viviana at nmt.edu

We report 1.3 cm and 6 cm continuum observations toward the massive proto-stellar candidate G11.11-0.12P1 using the Karl G. Jansky Very Large Array (VLA). We detect a string of four unresolved radio continuum sources coincident with the mid-IR source in G11P1. The continuum sources have positive spectral indices consistent with a thermal (free-free) ionized jet. The most likely origin of the ionized gas are shocks due to the interaction of a stellar wind with the surrounding high-density material. We also present NIR United Kingdom Infrared Telescope (UKIRT) archival data which show an extended structure detected only at K-band (2.2 \( \mu \text{m} \)), which is oriented perpendicular to the jet, and that may be scattered light from a circumstellar disk around the massive protostar. Our observations plus the UKIRT archival data thus provide new evidence that a disk/jet system is present in the massive protostellar candidate located in the G11.11-0.12P1 core.

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Formation of close in Super-Earths & Mini-Neptunes: Required Disk Masses & Their Implications

Hilke E. Schlichting\(^1\)

\(^1\) Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139-4307, USA
Recent observations by the Kepler space telescope have led to the discovery of more than 4000 exoplanet candidates consisting of many systems with Earth- to Neptune-sized objects that reside well inside the orbit of Mercury, around their respective host stars. How and where these close-in planets formed is one of the major unanswered questions in planet formation. Here we calculate the required disk masses for \textit{in situ} formation of the Kepler planets. We find that, if close-in planets formed as \textit{isolation masses}, then standard gas-to-dust ratios yield corresponding gas disks that are gravitationally unstable for a significant fraction of systems, ruling out such a scenario. We show that the maximum width of a planet’s accretion region in the absence of any migration is $2v_{\text{esc}}/\Omega$, where $v_{\text{esc}}$ is the escape velocity of the planet and $\Omega$ the Keplerian frequency and use it to calculate the required disk masses for \textit{in situ} formation with giant impacts. Even with giant impacts, formation without migration requires disk surface densities in solids at semi-major axes less than 0.1 AU of $10^3$–$10^5$ g cm$^{-2}$ implying typical enhancements above the minimum-mass solar nebular (MMSN) by at least a factor of 20. Corresponding gas disks are below, but not far from, the gravitational stability limit. In contrast, formation beyond a few AU is consistent with MMSN disk masses. This suggests that migration of either solids or fully assembled planets is likely to have played a major role in the formation of close-in super-Earths and mini-Neptunes. 

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The Herschel/PACS view of the CepOB2 region: Global protoplanetary disk evolution and clumpy star formation

A. Sicilia-Aguilar$^{1,2}$, V. Roccatagliata$^3$, K. Getman, $^4$, P. Riviere-Marichalar$^{5,2}$, T. Birnstiel$^6$, B. Merin$^7$, M. Fang$^2$, Th. Henning$^8$, C. Eiroa$^2$ and T. Currie$^9$

$^1$ SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, UK
$^2$ Departamento de Física Teórica, Facultad de Ciencias, Universidad Autónoma de Madrid, 28049 Cantoblanco, Madrid, Spain
$^3$ Universitäts-Sternwarte München, Ludwig-Maximilians-Universität, Scheinerstr. 1, 81679 München, Germany
$^4$ Department of Astronomy & Astrophysics, 525 Davey Laboratory, Pennsylvania State University, University Park PA 16802
$^5$ Kapteyn Astronomical Institute, P.O. Box 800, 9700 AV Groningen, The Netherlands
$^6$ Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge MA 02138, USA
$^7$ Herschel Science Centre, ESAC-ESA. PO Box 78. E-28691 Villanueva de la Cañada, Madrid, Spain
$^8$ Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany
$^9$ Department of Astronomy & Astrophysics, University of Toronto, Canada

E-mail contact: asa5 at st-andrews.ac.uk

The CepOB2 region, with its two intermediate-aged clusters Tr 37 and NGC 7160, is a paradigm of sequential star formation and an ideal site for studies of protoplanetary disk evolution. We use Herschel data to study the protoplanetary disks and the star formation history of the region. Herschel/PACS observations at 70 and 160 \textmu m probe the disk properties (mass, dust sizes, structure) and evolutionary state of a large number of young stars. Far-IR data also trace the remnant cloud material and small-scale cloud structure. We detect 95 protoplanetary disks at 70 \textmu m, 41 at 160 \textmu m, and obtain upper limits for more than 130 objects. The detection fraction at 70 \textmu m depends on the spectral type (88% for K4 or earlier stars, 17% for M3 or later stars) and on the disk type ($\sim$50% for full and pre-transitional disks, $\sim$35% for transitional disks, no low-excess/depleted disks detected). Non-accreting disks are not detected, suggesting significantly lower masses. Accreting transition and pre-transition disks have systematically higher 70 \textmu m excesses than full disks, suggestive of more massive, flared and/or thicker disks. Herschel data also reveal several mini-clusters in Tr37, small, compact structures containing a few young stars surrounded by nebulosity. Far-IR data are an excellent probe of the evolution of disks that are too faint for submillimetre observations. We find a strong link between far-IR emission and accretion, and between the inner and outer disk structure. Herschel confirms the dichotomy between accreting and non-accreting transition disks. Accretion is a powerful measure of global disk evolution: Substantial mass depletion and global evolution need to occur to shut down accretion in a protoplanetary disk, even if the disk has inner holes. Disks likely follow different evolutionary paths: Low disk masses do not imply opening inner holes, and having inner holes does not require low disk masses. The mini-clusters reveal multi-episodic star formation in Tr37.
The long survival of mini-clusters suggest that they formed from the fragmentation of the same core. Their various morphologies favour different formation/triggering mechanisms acting within the same cluster. The beads-on-a-string structure in one mini-cluster is consistent with gravitational fragmentation/focusing acting on very small scales (solar-mass stars in $\sim 0.5$ pc filaments). Multi-episodic star formation could also produce evolutionary variations between disks in the same region. Finally, Herschel also unveils what could be the first heavy mass loss episode of the O6.5 star HD 206267 in Tr 37.

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A Search For Star Formation in the Smith Cloud

David V. Stark$^1$, Ashley D. Baker$^1$, Sheila J. Kannappan$^1$

$^1$ Physics and Astronomy Department, University of North Carolina, Chapel Hill, NC 27516

E-mail contact: dstark at email.unc.edu

Motivated by the idea that a subset of HVCs trace dark matter substructure in the Local Group, we search for signs of star formation in the Smith Cloud, a nearby $\sim 2 \times 10^6 M_\odot$ HVC currently falling into the Milky Way. Using GALEX NUV and WISE/2MASS NIR photometry, we apply a series of color and apparent magnitude cuts to isolate candidate O and B stars that are plausibly associated with the Smith Cloud. We find an excess of stars along the line of sight to the cloud, but not at a statistically significant level relative to a control region. The number of stars found in projection on the cloud after removing an estimate of the contamination by the Milky Way implies an average star formation rate surface density of $10^{-4.8 \pm 0.3} M_\odot \text{yr}^{-1} \text{kpc}^{-2}$, assuming the cloud has been forming stars at a constant rate since its first passage through the Milky Way $\sim 70$ Myr ago. This value is consistent with the star formation rate expected based on the average gas density of the cloud. We also discuss how the newly discovered star forming galaxy Leo P has very similar properties to the Smith Cloud, but its young stellar population would not have been detected at a statistically significant level using our method. Thus, we cannot yet rule out the idea that the Smith Cloud is really a dwarf galaxy.

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The Impact of Chromospheric Activity on Observed Initial Mass Functions

Keivan G. Stassun$^{1,2}$, Aleks Scholz$^3$, Trent Dupuy$^4$ and Kaitlin Kratter$^5$

$^1$ Vanderbilt University, USA
$^2$ Fisk University, USA
$^3$ University of St. Andrews, UK
$^4$ University of Texas at Austin, USA
$^5$ University of Arizona, USA

E-mail contact: keivan.stassun at vanderbilt.edu

Using recently established empirical calibrations for the impact of chromospheric activity on the radii, effective temperatures, and estimated masses of active low-mass stars and brown dwarfs, we reassess the shape of the initial mass function (IMF) across the stellar/substellar boundary in the Upper Sco star-forming region (age $\sim 5-10$ Myr). We adjust the observed effective temperatures to warmer values using the observed strength of the chromospheric H$\alpha$ emission, and redetermine the estimated masses of objects using pre–main-sequence evolutionary tracks in the H-R diagram. The effect of the activity-adjusted temperatures is to shift the objects to higher masses by 3–100%. While the slope of the resulting IMF at substellar masses is not strongly changed, the peak of the IMF does shift from $\approx 0.06$ to $\approx 0.11 M_\odot$. Moreover, for objects with masses $< 0.2 M_\odot$, the ratio of brown dwarfs to stars changes from $\sim 80\%$ to $\sim 33\%$. These results suggest that activity corrections are essential for studies of the substellar mass function, if the masses are estimated from spectral types or from effective temperatures.

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Modeling MHD accretion-ejection: episodic ejections of jets triggered by a mean-field disk dynamo
Deniss Stepanovs¹, Christian Fendt¹ and Somayeh Sheikhnezami¹

¹ Max Planck Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany
E-mail contact: stepanovs at mpia.de

We present MHD simulations exploring the launching, acceleration, and collimation of jets and disk winds. The evolution of the disk structure is consistently taken into account. Extending our earlier studies, we now consider the self-generation of the magnetic field by an $\alpha^2\Omega$ mean-field dynamo. The disk magnetization remains on a rather low level, which helps to evolve the simulations for $T > 10,000$ dynamical time steps on a domain extending 1500 inner disk radii. We find the magnetic field of the inner disk to be similar to the commonly found open field structure, favoring magneto-centrifugal launching. The outer disk field is highly inclined and predominantly radial. Here, differential rotation induces a strong toroidal component, which plays a key role in outflow launching. These outflows from the outer disk are slower, denser, and less collimated. If the dynamo action is not quenched, magnetic flux is continuously generated, diffuses outward through the disk, and fills the entire disk. We have invented a toy model triggering a time-dependent mean-field dynamo. The duty cycles of this dynamo lead to episodic ejections on similar timescales. When the dynamo is suppressed as the magnetization falls below a critical value, the generation of the outflows and also accretion is inhibited. The general result is that we can steer episodic ejection and large-scale jet knots by a disk-intrinsic dynamo that is time-dependent and regenerates the jet-launching magnetic field.

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Characterizing the Youngest Herschel-detected Protostars I. Envelope Structure Revealed by CARMA Dust Continuum Observations
John J. Tobin¹,²,³,⁸ Amelia M. Stutz², S. Thomas Megeath¹,³, William J. Fischer³,⁹ Thomas Henning², Sarah E. Ragan², Babar Ali⁴, Thomas Stanke⁵, P. Manoj⁶, Nuria Calvet⁷ and Lee Hartmann⁷

¹ National Radio Astronomy Observatory, USA
² Max Planck Institute for Astronomy, Germany
³ University of Toledo, USA
⁴ NASA Herschel Science Center, USA
⁵ European Southern Observatory, Germany
⁶ Tata Institute of Fundamental Research, India
⁷ University of Michigan, USA
⁸ Leiden Observatory, The Netherlands
⁹ NASA Goddard Space Flight Center, USA
E-mail contact: tobin at striw.leidenuniv.nl

We present CARMA 2.9 mm dust continuum emission observations of a sample of 14 Herschel-detected Class 0 protostars in the Orion A and B molecular clouds, drawn from the PACS Bright Red Sources (PBRS) sample (Stutz et al.). These objects are characterized by very red 24 $\mu$m to 70 $\mu$m colors and prominent submillimeter emission, suggesting that they are very young Class 0 protostars embedded in dense envelopes. We detect all of the PBRS in 2.9 mm continuum emission and emission from 4 protostars and 1 starless core in the fields toward the PBRS; we also report 1 new PBRS source. The ratio of 2.9 mm luminosity to bolometric luminosity is higher by a factor of $\sim 5$ on average, compared to other well-studied protostars in the Perseus and Ophiuchus clouds. The 2.9 mm visibility amplitudes for 6 of the 14 PBRS are very flat as a function of uv-distance, with more than 50% of the source emission arising from radii $< 1500$ AU. These flat visibility amplitudes are most consistent with spherically symmetric envelope density profiles with $\rho \propto R^{-2.5}$. Alternatively, there could be a massive unresolved structure like a disk or a high-density inner envelope departing from a smooth power-law. The large amount of mass on scales $< 1500$ AU (implying high average central densities) leads us to suggest that the PBRS with flat visibility amplitude profiles are the youngest PBRS and may be undergoing a brief phase of high mass infall/accretion and are possibly among the youngest Class 0 protostars. The PBRS with more rapidly declining visibility amplitudes still have large envelope masses, but could be slightly more evolved.
The VLA Nascent Disk And Multiplicity (VANDAM) Survey of Perseus Protostars. Resolving the Sub-Arcsecond Binary System in NGC 1333 IRAS2A

John J. Tobin\textsuperscript{1,11}, Michael M. Dunham\textsuperscript{2}, Leslie W. Looney\textsuperscript{3}, Zhi-Yun Li\textsuperscript{4}, Claire J. Chandler\textsuperscript{1}, Dominique Segura-Cox\textsuperscript{1}, Sarah I. Sadavoy\textsuperscript{5}, Carl Melis\textsuperscript{6}, Robert J. Harris\textsuperscript{3}, Laura M. Perez\textsuperscript{1}, Kaitlin Kratter\textsuperscript{7}, Jes K. Jorgensen\textsuperscript{8}, Adele L. Plunkett\textsuperscript{9} and Charles L. H. Hull\textsuperscript{10}

\textsuperscript{1} National Radio Astronomy Observatory, USA
\textsuperscript{2} Harvard-Smithsonian Center for Astrophysics, USA
\textsuperscript{3} University of Illinois, USA
\textsuperscript{4} University of Virginia, USA
\textsuperscript{5} Max Planck Institute for Astronomy, Germany
\textsuperscript{6} University of California San Diego, USA
\textsuperscript{7} University of Arizona, USA
\textsuperscript{8} Centre for Star and Planet Formation & Natural History Museum of Denmark, University of Copenhagen, Denmark
\textsuperscript{9} Yale University, USA
\textsuperscript{10} University of California Berkeley, USA
\textsuperscript{11} Leiden Observatory, The Netherlands

E-mail contact: tobin at strw.leidenuniv.nl

We are conducting a Jansky VLA Ka-band (8 mm and 1 cm) and C-band (4 cm and 6.4 cm) survey of all known protostars in the Perseus Molecular Cloud, providing resolution down to $\sim 0.06''$ and $\sim 0.35''$ in Ka-band and C-band, respectively. Here we present first results from this survey that enable us to examine the source NGC 1333 IRAS2A in unprecedented detail and resolve it into a proto-binary system separated by $0.621'' \pm 0.006''$ ($\sim 143$ AU) at 8 mm, 1 cm, and 4 cm. These 2 sources (IRAS2A VLA1 and VLA2) are likely driving the two orthogonal outflows known to originate from IRAS2A. The brighter source IRAS2A VLA1 is extended perpendicular to its outflow in the VLA data, with a deconvolved size of 0.055'' ($\sim 13$ AU), possibly tracing a protostellar disk. The recently reported candidate companions (IRAS2A MM2 and MM3) are not detected in either our VLA data, CARMA 1.3 mm data, or SMA 850 $\mu$m data. SMA CO ($J = 3 \rightarrow 2$), CARMA CO ($J = 2 \rightarrow 1$), and lower resolution CARMA CO ($J = 1 \rightarrow 0$) observations are used to examine the outflow origins and the nature of the candidate companions to IRAS2A VLA1. The CO ($J = 3 \rightarrow 2$) and ($J = 2 \rightarrow 1$) data show that IRAS2A MM2 is coincident with a bright CO emission spot in the east-west outflow, and IRAS2A MM3 is within the north-south outflow. In contrast, IRAS2A VLA2 lies at the east-west outflow symmetry point. We propose that IRAS2A VLA2 is the driving source of the East-West outflow and a true companion to IRAS2A VLA1, whereas IRAS2A MM2 and MM3 may not be protostellar.
IRAS 16293–2422 is a well studied low-mass protostar characterized by a strong level of deuterium fractionation. In the line of sight of the protostellar envelope, an additional absorption layer, rich in singly and doubly deuterated water has been discovered by a detailed multiline analysis of HDO. To model the chemistry in this source, the gas-grain chemical code Nautilus has been used with an extended deuterium network. For the protostellar envelope, we solve the chemical reaction network in infalling fluid parcels in a protostellar core model. For the foreground cloud, we explored several physical conditions (density, cosmic ionization rate, C/O ratio). The main results of the paper are that gas-phase abundances of H$_2$O, HDO and D$_2$O observed in the inner regions of IRAS16293–24222 are lower than those predicted by a 1D dynamical/chemical (hot corino) model in which the ices are fully evaporated. The abundance in the outer part of the envelope present chaotic profiles due to adsorption/evaporation competition, very different from the constant abundance assumed for the analysis of the observations. We also found that the large abundances of gas-phase H$_2$O, HDO and D$_2$O observed in the absorption layer are more likely explained by exothermic surface reactions rather than photodesorption processes.

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The JCMT Legacy Survey of the Gould Belt: a molecular line study of the Ophiucbus molecular cloud

Glenn J. White$^{1,2}$, Emily Drabek-Maunder$^{3,11}$, Erik Rosolowsky$^4$, Derek Ward-Thompson$^5$, C.J. Davis$^8$, Jon Gregson$^9$, Jenny Hatchell$^1$, Miireya Etxaluze$^2$, Sarah Stickler$^4$, Jane Buckle$^7$, Doug Johnstone$^{6,9,15}$, Rachel Friesen$^{14}$, Sarah Sadavoy$^9$, Kieran. V. Natt$^1$, Malcolm Currie$^9$, J. S. Richer$^7$, Kate Pattle$^5$, Marco Spaans$^{10}$, James Di Francesco$^{5,12}$ and M.R. Hogerheijde$^{13}$

1 RALSpace, The Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire, OX11 0QX, England
2 Department of Physics and Astronomy, The Open University, Walton Hall, Milton Keynes, MK7 6AA, England
3 Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, England
4 Department of Physics, University of Alberta, 4-181 CCIS Edmonton AB T6G 2E1, Canada
5 Jeremiah Horrocks Institute, University of Central Lancashire, Preston, Lancashire, PR1 2HE, England
6 National Research Council Canada, 5071 West Saanich Road, Victoria, BC, V9E 2E7, Canada
7 Astrophysics Group, Cavendish Laboratory, J J Thomson Avenue, Cambridge CB3 0HE, England
8 Astrophysics Research Institute, Liverpool John Moores University, Birkenhead, Wirral, CH4 1LD, England
9 Joint Astronomy Centre, 660 N. A’ohoku Place, University Park, Hilo, Hawaii 96720, USA
10 Kapteyn Astronomical Institute, Postbus 800, 9700 AV, Groningen, Holland
11 Imperial College, Blackett Laboratory, Prince Consort Road, London SW7 2AZ, England
12 National Research Council Canada, 5071 West Saanich Rd, Victoria, BC, V9E 2E7, Canada
13 Leiden Observatory, Leiden University, PO Box 9513, 2300 RA, The Netherlands
14 Dunlap Institute for Astronomy & Astrophysics, University of Toronto, 50 St. George St., Toronto, ON, M5S 3H4, Canada
15 Department of Physics and Astronomy, University of Victoria, Victoria, BC, V8P 1A1, Canada

E-mail contact: glenn.white at open.ac.uk

CO, $^{13}$CO and C$^{18}$O $J = 3-2$ observations are presented of the Ophiuchus molecular cloud. The $^{13}$CO and C$^{18}$O emission is dominated by the Oph A clump, and the Oph B1, B2, C, E, F and J regions. The optically thin(ner) C$^{18}$O line is used as a column density tracer, from which the gravitational binding energy is estimated to be $4.5 \times 10^{39}$ J (2282 $M_\odot$ km$^2$ s$^{-2}$). The turbulent kinetic energy is $6.3 \times 10^{38}$ J (320 $M_\odot$ km$^2$ s$^{-2}$), or 7 times less than this, and therefore the Oph cloud as a whole is gravitationally bound. Thirty protostars were searched for high velocity gas, with eight showing outflows, and twenty more having evidence of high velocity gas along their lines-of-sight. The total outflow kinetic energy is $1.3 \times 10^{38}$ J (67 $M_\odot$ km$^2$ s$^{-2}$), corresponding to 21% of the cloud's turbulent kinetic energy. Although turbulent injection by outflows is significant, but does not appear to be the dominant source of turbulence in the cloud. 105 dense molecular clumplets were identified, which had radii $\sim 0.01–0.05$ pc, virial masses $\sim 0.1–12 M_\odot$, luminosities $\sim 0.001–0.1$ K km s$^{-1}$ pc$^{-2}$, and excitation temperatures $\sim 10–50$K. These are consistent with the standard GMC based size-line width relationships, showing that the scaling laws extend down to size scales of hundredths of a parsec, and to sub solar-mass condensations. There is however no compelling evidence that the majority of clumplets are undergoing free-fall collapse, nor that they are pressure confined.
NGC 7538 IRS1: Interaction of a polarized dust spiral and a molecular outflow

M.C.H. Wright\textsuperscript{1}, Charles L.H. Hull\textsuperscript{1}, Thushara Pillai\textsuperscript{2}, Jun-Hui Zhao\textsuperscript{3}, Göran Sandell\textsuperscript{4}

\textsuperscript{1} Department of Astronomy, University of California, Berkeley, Berkeley, CA 94720, USA
\textsuperscript{2} Max Planck Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn
\textsuperscript{3} Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
\textsuperscript{4} SOFIA-USRA, NASA Ames Research Center, MS 232-12, Building N232, Rm. 146, P.O. Box 1, Moffett Field, CA 94035-0001, USA

E-mail contact: tpillai.astro@gmail.com

We present dust polarization and CO molecular line images of NGC 7538 IRS1. We combined data from the SMA, CARMA and JCMT telescopes to make images with 2\textquoteleft.5 resolution at 230 and 345 GHz. The images show a remarkable spiral pattern in both the dust polarization and molecular outflow. These data dramatically illustrate the interplay between a high infall rate onto IRS1 and a powerful outflow disrupting the dense, clumpy medium surrounding the star. The images of the dust polarization and the CO outflow presented here provide observational evidence for the exchange of energy and angular momentum between the infall and the outflow. The spiral dust pattern, which rotates through over 180\degree from IRS1, may be a clumpy filament wound up by conservation of angular momentum in the infalling material. The redshifted CO emission ridge traces the dust spiral closely through the MM dust cores, several of which may contain protostars. We propose that the CO maps the boundary layer where the outflow is ablating gas from the dense gas in the spiral.

ALMA observations of a misaligned binary protoplanetary disk system in Orion

J.P. Williams\textsuperscript{1}, R.K. Mann\textsuperscript{2}, J. Di Francesco\textsuperscript{2,3}, S.M. Andrews\textsuperscript{4}, A.M. Hughes\textsuperscript{5}, L. Ricci\textsuperscript{4}, J. Bally\textsuperscript{6}, D. Johnstone\textsuperscript{2,3,7} and B. Matthews\textsuperscript{2,3}

\textsuperscript{1} Institute for Astronomy, University of Hawaii, Honolulu, HI 96816, USA
\textsuperscript{2} NRC Herzberg Astronomy and Astrophysics, 5071 West Saanich Road, Victoria, BC, V9E 2E7, Canada
\textsuperscript{3} Department of Physics and Astronomy, University of Victoria, Victoria, BC, V8P 1A1, Canada
\textsuperscript{4} Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
\textsuperscript{5} Van Vleck Observatory, Astronomy Department, Wesleyan University, 96 Foss Hill Drive, Middletown, CT 06459, USA
\textsuperscript{6} CASA, University of Colorado, CB 389, Boulder, CO 80309, USA
\textsuperscript{7} Joint Astronomy Centre, 660 North A\’ohoku Place, University Park, Hilo, HI 96720, USA

E-mail contact: jpw@ifhawaii.edu

We present ALMA observations of a wide binary system in Orion, with projected separation 440 AU, in which we detect submillimeter emission from the protoplanetary disks around each star. Both disks appear moderately massive and have strong line emission in CO 3–2, HCO\textsuperscript{+} 4–3, and HCN 3–2. In addition, CS 7–6 is detected in one disk. The line-to-continen\t
tal ratios are similar for the two disks in each of the lines. From the resolved velocity gradients across each disk, we constrain the masses of the central stars, and show consistency with optical-infrared spectroscopy, both indicative of a high mass ratio \sim 9. The small difference between the systemic velocities indicates that the binary orbital plane is close to face-on. The angle between the projected disk rotation axes is very high, \sim 72\degree, showing that the system did not form from a single massive disk or a rigidly rotating cloud core. This finding, which adds to related evidence from disk geometries in other systems, protostellar outflows, stellar rotation, and similar recent ALMA results, demonstrates that turbulence or dynamical interactions act on small scales well below that of molecular cores during the early stages of star formation.

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Spitzer IRAC Color Diagnostics for Extended Emission in Star-Forming Regions
Jason E. Ybarra\textsuperscript{1}, Mauricio Tapia\textsuperscript{1}, Carlos G. Román-Zúñiga\textsuperscript{1} and Elizabeth Lada\textsuperscript{2}

\textsuperscript{1} Instituto de Astronomía, Universidad Nacional Autónoma de México, 22860 Ensenada BC, Mexico
\textsuperscript{2} Department of Astronomy, University of Florida, Gainesville, FL 32611, USA
E-mail contact: jybarra at astro.unam.mx

The infrared data from the Spitzer Space Telescope are an invaluable tool for identifying physical processes in star formation. In this study, we calculate the Infrared Array Camera (IRAC) color space of UV fluorescent H\textsubscript{2} and polycyclic aromatic hydrocarbon (PAH) emission in photodissociation regions (PDRs) using the Cloudy code with PAH opacities from Draine & Li. We create a set of color diagnostics that can be applied to study the structure of PDRs and to distinguish between FUV-excited and shock-excited H\textsubscript{2} emission. To test this method, we apply these diagnostics to Spitzer IRAC data of NGC 2316. Our analysis of the structure of the PDR is consistent with previous studies of the region. In addition to UV excited emission, we identify shocked gas that may be part of an outflow originating from the cluster.

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\url{http://arxiv.org/pdf/1409.1238}
\url{http://stacks.iop.org/2041-8205/794/L25}

Migration and Growth of Protoplanetary Embryos I: Convergence of Embryos in Protoplanetary Disks
Xiaojia Zhang\textsuperscript{1}, Beibei Liu\textsuperscript{2}, Douglas N.C. Lin\textsuperscript{1,3}, Hui Li\textsuperscript{4}

\textsuperscript{1} Department of Astronomy and Astrophysics, University of California, Santa Cruz, CA 95064, USA
\textsuperscript{2} Kavli Institute for Astronomy & Astrophysics and Department of Astronomy, School of Physics, Peking University, Beijing 100871, China
\textsuperscript{3} Institute for Advanced Studies, Tsinghua University, Beijing 100084, China
\textsuperscript{4} Los Alamos National Laboratory, Los Alamos, NM 87545, USA
E-mail contact: xzhang47 at ucsb.edu

According to the core-accretion scenario, planets form in protostellar disks through the condensation of dust, coagulation of planetesimals, and emergence of protoplanetary embryos. At a few AU in a minimum mass nebula, embryos’ growth is quenched by dynamical isolation due to the depletion of planetesimals in their feeding zone. However, embryos with masses ($M_p$) in the range of a few Earth masses ($M_\oplus$) migrate toward a transition radius between the inner viscously heated and outer irradiated regions of their natal disk. Their limiting isolation mass increases with the planetesimals surface density. When $M_p > 10 M_\oplus$, embryos efficiently accrete gas and evolve into cores of gas giants. We use numerical simulation to show that, despite streamline interference, convergent embryos essentially retain the strength of non-interacting embryos’ Lindblad and corotation torque by their natal disks. In disks with modest surface density (or equivalently accretion rates), embryos capture each other in their mutual mean motion resonances and form a convoy of super Earths. In more massive disks, they could overcome these resonant barriers to undergo repeated close encounters including cohesive collisions which enable the formation of massive cores.

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Accreting Circumplanetary Disks: Observational Signatures
Zhaohuan Zhu\textsuperscript{1}

\textsuperscript{1} Princeton University, 4th Ivy Lane, Princeton, NJ, 08540, USA
E-mail contact: zzhhu at astro.princeton.edu

I calculate the spectral energy distributions (SEDs) of accreting circumplanetary disks using atmospheric radiative transfer models. Circumplanetary disks only accreting at $10^{-10} M_\odot yr^{-1}$ around a 1 $M_J$ planet can be brighter than the planet itself. A moderately accreting circumplanetary disk ($\dot{M} \sim 10^{-8} M_\odot yr^{-1}$; enough to form a 10 $M_J$ planet
within 1 Myr) around a 1 M_J planet has a maximum temperature of ~2000 K, and at near-infrared wavelengths (J, H, K bands), this disk is as bright as a late M-type brown dwarf or a 10 M_J planet with a "hot start". To use direct imaging to find the accretion disks around low mass planets (e.g., 1 M_J) and distinguish them from brown dwarfs or hot high mass planets, it is crucial to obtain photometry at mid-infrared bands (L', M, N bands) because the emission from circumplanetary disks falls off more slowly towards longer wavelengths than those of brown dwarfs or planets. If young planets have strong magnetic fields (>100 G), fields may truncate slowly accreting circumplanetary disks (\( \dot{M} < 10^{-9} M_\odot yr^{-1} \)) and lead to magnetospheric accretion, which can provide additional accretion signatures, such as UV/optical excess from the accretion shock and line emission.

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http://arxiv.org/pdf/1408.6554

Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the Newsletter bounces back from an address for three consecutive months, the address is deleted from the mailing list.
Herbig AeBe stars: Multiplicity and consequences
Gaspard Duchêne\textsuperscript{1,2}

\textsuperscript{1} Astronomy Department, University of California, Berkeley, CA 94720-3411 USA
\textsuperscript{2} Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France
CNRS, IPAG, F-38000 Grenoble, France

E-mail contact: gduchene at berkeley.edu

By virtue of their young age and intermediate mass, Herbig AeBe stars represent a cornerstone for our understanding of the mass-dependency of both the stellar and planetary formation processes. In this contribution, I review the current state-of-the-art multiplicity surveys of Herbig AeBe stars to assess both the overall frequency of companions and the distribution of key orbital parameters (separation, mass ratio and eccentricity). In a second part, I focus on the interplay between the multiplicity of Herbig AeBe stars and the presence and properties of their protoplanetary disks. Overall, it appears that both star and planet formation in the context of intermediate-mass stars proceeds following similar mechanisms as lower-mass stars.

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http://arxiv.org/pdf/1410.5883

Formation of stars and clusters over cosmological time
Bruce G. Elmegreen\textsuperscript{1}

\textsuperscript{1} IBM Research Division, T.J. Watson Research Center, 1101 Kitchawan Road, Yorktown Heights, NY 10598

E-mail contact: bge at watson.ibm.com

The concept that stars form in the modern era began some 60 years ago with the key observation of expanding OB associations. Now we see that these associations are an intermediate scale in a cascade of hierarchical structures that begins on the ambient Jeans length close to a kiloparsec in size and continues down to the interiors of clusters, perhaps even to binary and multiple stellar systems. The origin of this structure lies with the dynamical nature of cloud and star formation, driven by supersonic turbulence and interstellar gravity. Dynamical star formation is relatively fast compared to the timescale for cosmic accretion, and then the star formation rate keeps up with the accretion rate, leading to a sequence of near-equilibrium states during galaxy formation and evolution. Dynamical star formation also helps to explain the formation of bound clusters, which require a local efficiency that exceeds the average by more than an order of magnitude. Efficiency increases with density in a hierarchically structured gas. Cluster formation should vary with environment as the relative degree of cloud self-binding varies, and this depends on the ratio of the interstellar velocity dispersion to the galaxy rotation speed. As this ratio increases, galaxies become more clumpy, thicker, and have more tightly bound star-forming regions. The formation of old globular clusters is understood in this context, with the metal-rich and metal-poor globulars forming in high-mass and low-mass galaxies, respectively, because of the galactic mass-metallicity relation. Metal-rich globulars remain in the disks and bulge regions where they formed, while metal-poor globulars get captured as parts of satellite galaxies and end up in today’s spiral galaxy halos. Blue globulars in the disk could have formed very early when the whole Milky Way had a low mass.

Accepted by conference “Lessons from the Local Group,” ed. K. Freeman et al., Springer, 2014
Despite the importance of massive stars as the main source of energy injection into the ISM of galaxies, their formation process is not clearly understood. To distinguish between the different theories it is crucial to establish how the parental cloud fragments by studying the distribution of low-mass stars in massive star cradles. The detection of this population is a challenge because it is highly embedded in the natal molecular material. Only deep IR, X-ray and radio/(sub)millimeter observations are able to penetrate into the massive star cradles and reveal the stellar population.

I have analyzed deep X-ray and IR archival surveys towards 3 nearby massive star forming regions (Orion, DR21 and Monoceros R2). I have studied the properties of the low-mass stellar population (e.g., spatial distribution, clustering, stellar densities, extinction distribution, evolutionary stages), and their feedback into the star-forming environment. In particular, I have evaluated how the outflow-driven turbulence in dense subclusters of low-mass stars can affect the formation of massive stars. I discuss my results in the context of the different massive star formation theories. I will also present new Very Large Array (VLA) and Submillimeter Array (SMA) observations of Orion and Monoceros R2, respectively. The multi-epoch VLA continuum data has allowed to study the nature of the radiovariability of Orion young stars. The SMA observations have revealed bright continuum emission and molecular hot cores towards the more massive stars and 11 previously unknown CO molecular outflows from the embedded stellar cluster.
Postdoctoral fellowship and PhD positions
Star- and planet formation, astrochemistry, early solar system

A 3 year postdoctoral fellowship and two 4-year PhD positions are available within the Molecular Astrophysics group located at Leiden Observatory and Max Planck Institute for Extraterrestrial Physics (MPE) in Garching. The postdoc and PhD students will be part of an international team studying the physical and chemical evolution from collapsing cores to planet-forming disks and exoplanets centered around ALMA data. A wide range of complementary data from Herschel as well as ground-based infrared and submillimeter spectroscopy is available.

The PhD students will be located at Leiden Observatory, whereas the postdoc can be located at either MPE, Leiden or a combination. The postdoc is expected to co-supervise PhD or MSc students and is encouraged to also pursue a personal research program. The postdoc appointment is initially for two years, with the possibility of renewal of 1 year. It can start anytime in 2015 (note typo in October newsletter).

Candidates with an observational and/or modeling background in astrochemistry, star formation (from small to galactic scales), circumstellar disks, submillimeter spectroscopy, planet formation and planet population synthesis models are encouraged to apply.

Both Leiden Observatory and MPE carry out observational, interpretative and theoretical research in the fields of the star and planet formation, laboratory astrophysics, galactic structure, the formation, dynamics and evolution of (high-redshift) galaxies and their nuclei, and cosmology.

Applications should include a curriculum vitae, publication list, and a brief statement of research experience and interests, and arrange for at least three letters of reference to be uploaded on the relevant website. Review of applications for the postdoc positions will start on November 15 2014. Deadline for the PhD position is December 1 2014.

Web site for submission:
postdocs: [http://jobs.strw.leidenuniv.nl/2015/dishoeckPD/](http://jobs.strw.leidenuniv.nl/2015/dishoeckPD/)
PhD: [http://www.strw.leidenuniv.nl/phd/apply.php](http://www.strw.leidenuniv.nl/phd/apply.php)

More information:
[http://www.strw.leidenuniv.nl/~ewine/](http://www.strw.leidenuniv.nl/~ewine/)
[http://www.strw.leidenuniv.nl/WISH/](http://www.strw.leidenuniv.nl/WISH/)
[http://www.mpe.mpg.de/ir](http://www.mpe.mpg.de/ir)
Florida Theoretical Astrophysics Postdoctoral Fellowship

The University of Florida (UF) Department of Astronomy invites applications for one or more postdoctoral fellowship positions in theoretical astrophysics, with an anticipated start date of Fall 2015. Successful candidate(s) will be expected to carry out original research in theoretical astrophysics, independently and/or in collaboration with UF faculty. They will have access to the UF High Performance Computing Center, as well as observational facilities, including the Gran Telescopio Canarias.

UF also has active observational and instrumentation groups. Candidates are encouraged to propose theoretical research that relates to existing research programs and/or facilities at UF, including planet formation and exoplanets, star and galaxy formation, and stellar populations. Further information, including a list of faculty and their research interests, is available at the above URLs.

The appointment is renewable annually for up to 3 years based on satisfactory performance, needs of the Department and College, and available funding. This position includes a benefits package. A Ph.D. in a relevant field by the starting date is required. Application materials (CV, publications list, statement of research interests and plans (max 5 pages), and three letters of reference) should be emailed to jctan@astro.ufl.edu with "Theory15" in the title. Application materials should be received by January 3rd, 2015 to ensure full consideration. For more information about the position, please contact Dr. Jonathan Tan.

see also https://jobregister.aas.org/job_view?JobID=49661

Postdoctoral Fellowship in Exo-Planets, Brown Dwarfs and Young Stars
- York University

Applications are invited for a postdoctoral fellowship at York University in Toronto. The successful candidate will work with Professor Ray Jayawardhana and his collaborators on observational and analytical studies of extra-solar planets, brown dwarfs and young stars, and will be encouraged to pursue independent research on related topics. Ongoing and recent projects include photometric and spectroscopic studies of extra-solar planets, high-contrast imaging searches for sub-stellar companions around young stars, investigations of brown dwarf variability and multiplicity, and the SONYC (Substellar Objects in Nearby Young Clusters) ultra-deep survey, using data from VLT, Subaru, Gemini, Keck, CFHT, Kepler, and other major observatories. The position is for two years, with extension to a third year possible, and comes with a competitive salary and funds for research expenses. Applicants should send their curriculum vitae, a description of research interests and plans and a list of publications, and should arrange for three letters of recommendation to be sent directly to marlene@yorku.ca. All materials should be submitted electronically. Applications received before 2014 December 1 will receive full consideration. Early expressions of interest and inquiries are welcome.
Post-Doctoral position in Exoplanet Research at ETH Zurich

The Institute for Astronomy, ETH Zurich, Star and Planet Formation Research Group invites applications for a new post-doctoral fellowship focused on exoplanet research with Dr. Sascha P. Quanz, Prof. Hans. Martin Schmid, and Prof. Michael R. Meyer. Research in our group covers several areas including the direct detection and characterization of extra-solar planets, the structure and evolution of circumstellar disks, and the formation and evolution of young star clusters. More information can be found at [http://www.astro.ethz.ch/meyer/index](http://www.astro.ethz.ch/meyer/index).

Successful applicants will have the opportunity to work with students at all levels and become involved in large programs in which our research group participates (for example the Guaranteed Time Program for the high-contrast imager SPHERE recently installed at ESO’s Very Large Telescope in Chile). Our group is also involved in the Swiss National Centre for Competence in Research (NCCR) Planets Project, an interdisciplinary and inter-institutional research program focused on the origin, evolution, and characterization of planets inside and outside the Solar System. More information can be found here [http://www.exoplanets.ch/nccr-planets/](http://www.exoplanets.ch/nccr-planets/).

Switzerland is a member of ESO and ESA, and successful applicants will have full access to their facilities. The Institute for Astronomy maintains access to a range of high performance computing options, including stand-alone machines, large clusters, and the resources of the Swiss National Supercomputing Center (CSCS). Interested applicants will also be welcome to explore research opportunities in the Astronomical Instrumentation Laboratory.

Salaries and duration of appointments will be commensurate with experience. Starting salaries begin at CHF 85,750, with initial appointments of 2+1 years, up to a maximum of six. Applications are invited from all nationalities and should consist of a CV and brief descriptions of past/proposed research (combined length not to exceed 6 pages). A separate publication list should be attached. Materials should be sent electronically in a single pdf file. This file, as well as three letters of reference (sent directly by the referees) should be sent to eth-astro-star-planet@phys.ethz.ch. Review of applications will begin December 1, 2014 and will continue until position is filled.

Meetings

Cloudy workshop, 2015 May 4 to 8, Copernicus Astronomical Center, Warsaw

Registration is now open for the 2015 May Cloudy workshop. It will be held May 4 to 8 at Nicolaus Copernicus Astronomical Center, Warsaw Poland.

Cloudy is a code that simulates diffuse gaseous environments. It calculates the plasma, chemistry, radiation transport, and dynamics problems simultaneously and self consistently, building from the foundation of individual atomic and molecular processes. The result is a prediction of the conditions in the material and its observed spectrum.

This workshop will cover observation, theory, and application of Cloudy to a wide variety of astronomical environments. This includes the theory of diffuse non-LTE matter and quantitative spectroscopy (the science of using spectra to make physical measurements). We will use Cloudy to simulate such objects as AGB stars, Active Galactic Nuclei, Starburst galaxies, and the intergalactic medium.

The sessions will consist of a mix of textbook study, using Osterbrock & Ferland, Astrophysics of Gaseous Nebul and Active Galactic Nuclei, application of the spectral-simulation code Cloudy to a variety of astrophysical problems, and projects organized by the participants. No prior experience with Cloudy is assumed. There is no registration fee and financial support is not available.


SOUL OF HIGH-MASS STAR FORMATION
March 15–20, 2015, Puerto Varas, Chile

We are pleased to announce that the Soul of High-Mass Star Formation conference will be held in Puerto Varas, Chile on March 15–20, 2015. The study of high-mass stars from both observational and theoretical point of view is complex and there is still no consensus on the key mechanisms leading to their formation. During the last decade many large-scale surveys (e.g. GLIMPSE, ATLASGAL) led to the identification of massive star formation regions in their earliest stages in our Galaxy. These have been observed with new instruments, in particular massive Herschel data has been taken to characterize physically and chemically the most embedded sources on moderate to large spatial scales. Today, when ALMA will soon begin full operations opening new windows in frequency, chemistry, spatial resolution, and sensitivity, it is timely to discuss our current understanding and open questions on massive star formation.

Key science topics to be discussed are:

- High-Mass Star Formation Theory and Simulations
- Early Stages of High-Mass Star Formation
- Cores and Filaments
- Chemistry
- Massive Disks
- Massive Jets/Outflows
- Massive Clusters
- Inner Galaxy
- Nearby Galaxies

For more information and to register, please visit: [http://www.das.uchile.cl/msf2015/](http://www.das.uchile.cl/msf2015/)
Summary of Upcoming Meetings

Triple Evolution & Dynamics in Stellar and Planetary Systems
15 - 21 November 2014 Haifa, Israel
[http://trendy-triple.weebly.com](http://trendy-triple.weebly.com)

The Kinematics of Star Formation: Theory and Observation in the Gaia Era
9 January 2015 London, UK
[http://www.star.herts.ac.uk/kinematics](http://www.star.herts.ac.uk/kinematics)

45th “Saas-Fee Advanced Course”:
From Protoplanetary Disks to Planet Formation
15-20 March 2015, Switzerland

The Soul of Massive Star Formation
15 - 20 March 2015 Puerto Varas, Chile

Star and Planet Formation in the Southwest
23 - 27 March 2015 Oracle, Arizona, USA
[https://lavinia.as.arizona.edu/~kkratter/SPF1/Home.html](https://lavinia.as.arizona.edu/~kkratter/SPF1/Home.html)

Cloudy Workshop
4 - 8 May 2015 Warsaw, Poland

Triple Evolution & Dynamics in Stellar and Planetary Systems
31 May - 5 June 2015 Haifa, Israel
[http://trendy-triple.weebly.com](http://trendy-triple.weebly.com)

Workshop on the Formation of the Solar System II
2 - 4 June 2015 Berlin, Germany
[https://indico.mpifr-bonn.mpg/FormationOfTheSolarSystem2](https://indico.mpifr-bonn.mpg/FormationOfTheSolarSystem2)

IGM@50: is the Intergalactic medium driving Star Formation?
8 - 12 June 2015 Abbazia di Spineto, Italy
[http://www.arcetri.astro.it/igm50](http://www.arcetri.astro.it/igm50)

30 Years of Photodissociation regions - A Symposium to honor David Hollenbach’s lifetime in science
28 June - 3 July 2015
[http://pdr30.strw.leidenuniv.nl](http://pdr30.strw.leidenuniv.nl)

Disc dynamics and planet formation
29 June - 3 July 2015 Larnaka, Cyprus
[http://www.star.uclan.ac.uk/discs2015](http://www.star.uclan.ac.uk/discs2015)

Cosmic Dust
17 - 21 August 2015 Tokyo, Japan
[https://www.cps-jp.org/~dust/](https://www.cps-jp.org/~dust/)

Extreme Solar Systems III
29 November - 4 December 2015 Hawaii, USA

The 19th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun
6 - 10 June 2016 Uppsala, Sweden