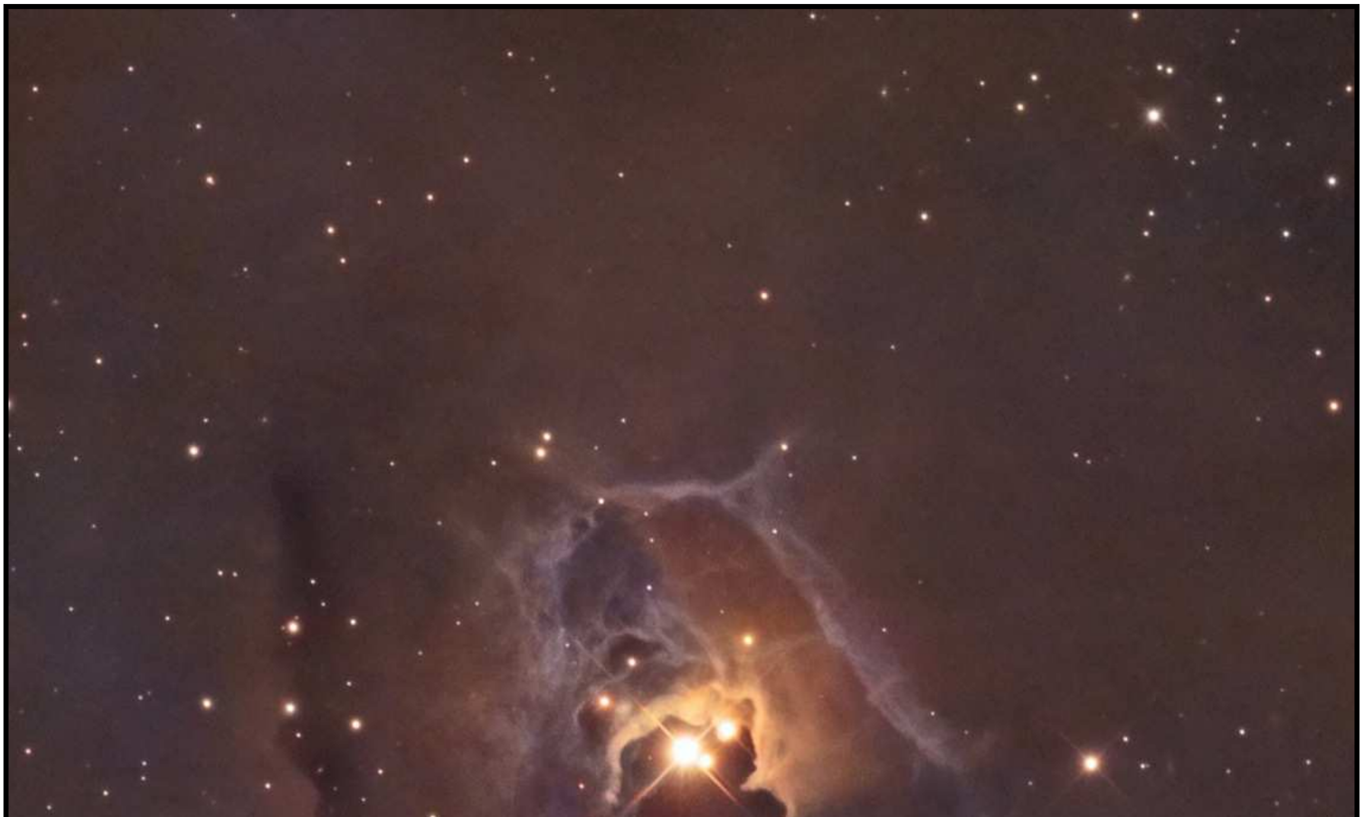
THE STAR FORMATION NEWSLETTER

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

No. 280 — 19 April 2016 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)



The Star Formation Newsletter

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

Newsletter Archive

www.ifa.hawaii.edu/users/reipurth/newsletter.htm

List of Contents

Cover Picture

HP Tau is a wellknown T Tauri star in Taurus. Cohen & Kuhi (1979) found it to be surrounded by three other young stars, HP Tau/G1, /G2, and /G3. Of the three bright stars within the central reflection nebula, HP Tau is the second brightest to the upper right. The brightest is G2 (= V1025 Tau) with G3 as its companion, both about 15" to the southeast of HP Tau. G1 is a fainter star about 20" to the north-northwest of HP Tau. This little group is located at a distance of 161.2±0.9 pc, a distance derived from trigonometric parallax measurements of G2 with the VLBA (Torres et al. 2009). The image has north up and east left.

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

Submitting your abstracts

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each Call for Abstracts. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/starformation/index.cfm

Perspective

Wide Planetary-Mass Companions to Young Stars

Adam L. Kraus

1 Discovery and Demographics

For two decades, high-resolution imaging surveys have been conducted from the ground (since Nakajima et al. 1995) and space (since Sartoretti et al. 1998) in order to directly detect analogs of the Solar System's gas giant planets. Direct imaging planet searches are technically challenging due to the need for both angular resolution (to resolve companions on solar system scales, with $a \leq 100$ AU) and high contrast (to identify companions that are near or below the deuterium burning limit, meeting one common definition of "planetary"), so the exploration of parameter space has proceeded slowly. A handful of massive Jovian companions have been discovered by imaging surveys to orbit on solar-system scales (e.g., Marois et al. 2008; Lagrange et al. 2009), and the first companion approaching $1M_{Jup}$, 51 Eri b, was only recently discovered (Macintosh et al. 2015). However, these searches also have turned up a larger set of bound companions that are nominally of planetary mass ($M \sim$5–20 M_{Jup}), but sit at much wider separations than the Solar System's gas giant planets ($\rho > 100$ AU). It remains unclear whether these objects are truly planetary in nature, given their wide orbits and super-Jovian masses, so I hereafter use the less value-laden term "planetary mass companions", or PMCs.

The broadly accepted prototype PMC is 2MASS J12073346 -3932539 b (or "2M1207b"; Chauvin et al. 2004), a 4–8 M_{Jup} companion separated by $\rho \sim 40$ AU from a 10–15 Myr old brown dwarf. Although the mass ratio is only modest ($q \sim 0.15$) and the projected separation is not much wider than the Solar System planets, 2M1207b clearly defied both of the demographic trends first identified by Bouy et al. (2003) and Burgasser et al. (2003) for brown dwarf binary systems: nearly all pairs are both tight ($a_{bin} < 10$ AU) and of similar mass ($q > 0.7$). The companion 2M1207b was therefore recognized as a potential new class of object and not simply an extreme binary.

The discovery of 2M1207b was soon followed by other PMC discoveries, including GQ Lup b (Neuhauser et al. 2005), DH Tau b (Itoh et al. 2005), and 1RXS J160929.1-210524 b (or 1RXSJ1609 b; Lafreniere et al. 2008b), all of which orbit stars (and hence have more extreme mass ratios, $q \leq 0.05$) and are found at wider projected separations ($\rho \sim$115-330 AU). A full description of the PMC sample is difficult to compile; no firm definition has been accepted by the community, and many are nebulously lumped in with more traditional-appearing planetary systems. An upcoming review of direct-imaging planet-searches (Bowler 2016, in prep) lists 8 directly imaged companions to young stars with masses near or below the deuterium limit, ages $\tau < 15$ Myr, projected separations ρ =100-1000 AU, and primary star masses $M_{prim} > 0.1M_{\odot}$. Many surveys have also been published that would have been sensitive to PMCs, but did not discover any; those with $\geq$20 targets in star-forming regions include Kraus et al. (2005, 2006), Ahmic et al. (2007), Lafreniere et al. (2008a), Biller et al. (2011), Kraus & Hillenbrand (2012), and Todorov et al. (2014).

Most known PMCs have been serendipitious discoveries or were found in surveys that have not published detection limits. The occurrence rate therefore remains poorly constrained. Ireland et al. (2011) estimated from two detections out of 49 targets that $F = 2/49 = 4.1^{+4.9}_{-1.3}\%$, before any completeness correction. Notably, both of the statistically useful companions were near the lower limit of the survey, with $M < 20M_{Jup}$, and no other companions with $M < 80M_{Jup}$ were found. This was interpreted as possible evidence for a mass function distinct from the binary population. Lafreniere et al. (2014) found 3 detections among 91 targets, measuring a combined occurrence rate of $F = 4.0^{+3.0}_{-1.2}\%$ for ρ =250–1000 AU and M =5–40 M_{Jup}. However, two of the additional companions had $M \sim 40M_{Jup}$, flattening the mass function. The number statistics remain small, so the frequency, mass function, and semimajor axis distribution are very uncertain.

2 Photospheric Properties and Circumsubstellar Disks

Near-infrared photometry is widely available for the PMC population, obtained either in the course of discovery or in dedicated followup programs. The color-magnitude and color-color sequences typically follow those of free floating young brown dwarfs of similar mass (e.g., Kraus et al. 2014 vs Kirkpatrick et al. 2008), showing systemati-

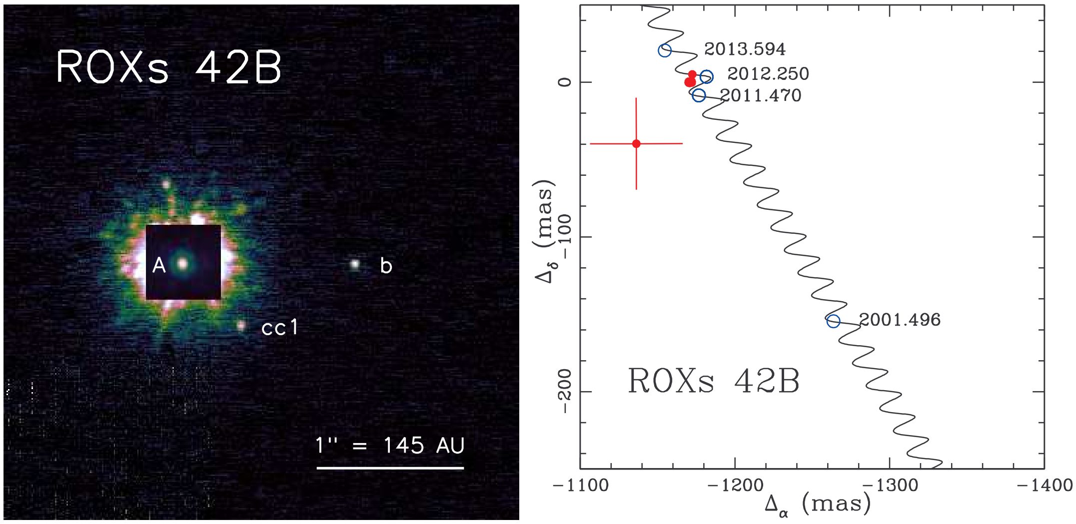


Figure 1: From Kraus et al. (2014). Left: K' image of ROXs42B, a standard example of a PMC. The candidate companion first reported by Ratzka et al. (2005) is apparent (b), as is a background star (cc1). The image uses a linear stretch that saturates at 110% of the peak brightness of b, except for a 0.5" box that uses a linear stretch saturating at 110% of the primary star peak. Right: Relative astrometry of ROXs42B b with respect to A, from Ratzka et al. (2005) and Kraus et al. (2014). The solid line shows the expected track for a nonmoving background star, shifted to minimize the weighted residuals with respect to best-fit positions (blue circles). ROXs42B b is clearly comoving, with a model-derived mass of $10 \pm 4 M_{Jup}$ and projected separation of $\rho = 140 \pm 10$ AU.

cally redder colors than older, more massive brown dwarfs of similar temperature (e.g., Dupuy & Liu 2012). For the subset of PMCs with NIR spectroscopic follow (e.g., McElwain et al. 2007; Bowler et al. 2011, 2014; Bonnefoy et al. 2014; Lachapelle et al. 2015), the spectra also resemble those of young free-floating brown dwarfs (e.g., Allers & Liu 2013), with spectral types between late-M and mid-L and characteristic signatures of youth that include a triangular H-band continuum and shallow alkali lines. Given the similarity between PMCs and free-floating counterparts, there is no evidence of non-solar bulk metallicity.

Spectroscopic and photometric surveys of PMCs have also revealed that many are vigorously accreting from circumsubstellar disks. The first indications of ongoing mass accretion were discovered in near-infrared spectra of GQ Lup b (Seifahrt et al. 2007), CT Cha b (Schmidt et al. 2008), and GSC 6214-210 b (Bowler et al. 2011), which show Paβ emission at $\lambda = 1.282\mu$m. FW Tau b was subsequently shown to host a rich set of optical and infrared emission lines by Bowler et al. (2014), consistent with the presence of accretion and outflows. Zhou et al. (2014) discovered similar evidence of mass accretion using optical-UV photometry from the Hubble Space Telescope. They constructed SEDs of GSC 6214-210 b, DH Tau b, and GQ Lup b, showing that all three have blue continuum excesses and Hα emission. Intriguingly, the mass accretion rates inferred from those observations are 1–2 orders of magnitude higher than those measured for free-floating brown dwarfs of similar mass (Herczeg et al. 2009).

Similarly, some PMCs have unusually red NIR colors that might denote disk excesses (e.g., Ireland et al. 2011), and the 1RXSJ1609 system has been reported to have a spatially unresolved excess at $\lambda = 24\mu$m (Bailey et al. 2013). ALMA observations of FW Tau b have revealed a circumsubstellar disk, with a mass of 1–2 M_{Earth} in millimeter-sized grains (Kraus et al. 2015) and millimeter emission lines from CO gas (Caceres et al. 2015). The solid mass is approximately ten times that of the Galilean satellites, while the photospheric flux of FW Tau b corresponds to a mass of 10 M_{Jup}, suggesting an intriguing analog of moon formation. However, some systems either have much lower disk masses or are in advanced stages of grain growth; Bowler et al. (2015) reported a nondetection to similar depth for GSC 6214-210 b, corresponding to an upper limit of $< 0.15 M_{Earth}$ of millimeter or smaller dust grains.

3 Competing Formation Models

Planetary-mass companions in ultrawide orbits pose a significant challenge to existing models of planet formation. There are four plausible processes that have been suggested as a way of producing PMCs in wide orbits. All of these models have significant caveats, but barring another plausible production channel, it seems that at least one of these processes must occur.

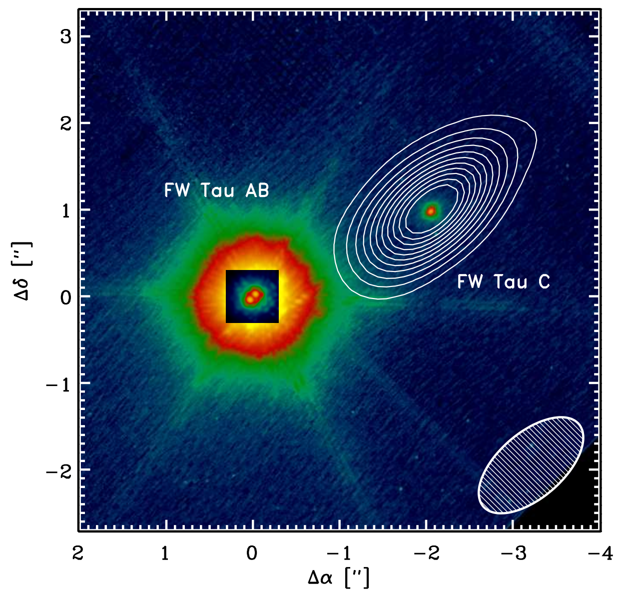


Figure 2: From Kraus et al. (2015), ALMA 1.3mm continuum contours (shown at $5\sigma \sim 0.14$ mJy beam^{-1} intervals) are overlaid on a near-infrared (K') image of the FW Tau system taken with the NIRC2 camera on the Keck-II telescope. The mm-wavelength continuum emission is centered on the faint companion (FW Tau C), denoting a mass of ∼1–2 M_{Earth} in millimeter or smaller particles.

At ages of $\tau < 0.1$ Myr, PMCs could form via prompt fragmentation after the prestellar core has begun free-fall collapse, but before the core has become nonisothermal and heating opposes further collapse (e.g., Bodenheimer & Burkert 2001, and references therein). In this model, PMCs would represent the extreme low-mass tail of wide binary formation. For solar-type primaries, the binary companion mass function appears to be flat in the stellar mass regime (Raghavan et al. 2010) and perhaps extending into the substellar regime (Metchev & Hillenbrand 2009), with all companion masses being equally likely. However, there is not sufficient evidence to know whether this trend continues down to planetary masses. A more fundamental limit is the need to prevent mass accretion. Initial fragment masses should fall near the opacity-limited minimum mass ($M \sim$3–10 M_{Jup}; Low & Lynden-Bell 1976; Bate 2005), so they could plausibly represent the PMC population. However, accretion from the envelope would quickly drive the mass into the stellar regime, as is thought to happen for the "first cores" that are an evolutionary step for all young stars (Tomida et al. 2013).

PMCs also might form in situ via fragmentation of massive disks that violate the Toomre stability criterion (Toomre 1964), a process that actually occurs most readily at the largest separations since cold gas with low shear is most subject to collapse (e.g., Boss 1988). This process could plausibly occur during the Class 0/I protostellar stage at ages $0.1 < \tau < 0.5$ Myr (Stamatellos & Whitworth 2009), also in analogy to a proposed binary formation channel, when the primary star is accreting most of its mass through a massive protostellar disk. This process is capable of producing fragments near the opacity-limited minimum mass, but it also suffers the same drawback that those fragments would accrete to stellar masses unless they formed exactly as the envelope was exhausted (Dodson-Robinson et al. 2009; Kratter et al. 2010). If fragmentation occurred instead in massive disks during the Class II stage (e.g., Boss 2011; Vorobyov 2013), after the envelope was exhausted, then the smaller reservoir of gas would prevent accretion up to the stellar mass regime. However, Class II disks around solar-type stars typically have M_{disk} ∼1–10 M_{Jup} (e.g., Andrews et al. 2013), so PMC formation would need to be a common outcome specifically among the small fraction of disks that are most massive (approaching $M_{disk} \sim 100 M_{Jup}$).

At ages of τ =1–10 Myr, wide PMCs also might form in situ via the coalescence of a solid core that subsequently accretes gas, in a wide-orbit analog to classical models of core accretion (e.g., Pollack et al. 1996). The classical picture of core accretion would have led to core assembly timescales that are unacceptably long at $a > 100$ AU, and indeed, most giant planet formation would probably occur at the ice line near a =1–2 AU. Subsequent adaptations have found that core accretion could extend outward to tens of AU (e.g., Dodson-Robinson et al. 2009; Rafikov 2011), but still not to the orbital regime of PMCs, and there is no obvious route for further extending this regime to extremely large radii.

Finally, PMCs might form at much smaller orbital radii, but then be ejected onto wide orbits via dynamical interactions; this process could occur at any age, though with decreasing frequency over time as only increasingly stable systems remain. This model would be a low-energy analog of the embryo ejection model for brown dwarf formation (Reipurth & Clarke 2001). A number of observational tests are beginning to yield evidence against this hypothesis. A large number of the youngest PMCs have circumsubstellar disks, despite the dynamical stripping that would occur in the close encounters needed to eject them from inner solar systems (e.g., Bowler et al. 2011). However, the presence of disks is not conclusive since they might be replenished by accretion from the circumprimary disk or envelope. While the orbital periods of PMCs are far too long for full orbit fits, measured orbit arcs also show substantial tangential motion (e.g., Ginski et al. 2014) that is not consistent with the highly eccentric orbits and almost purely radial motion that would result from ejections. Finally, ejection events preferentially eject the less massive object (Veras & Armitage 2004), and hence there should be close brown dwarf or stellar companions to PMC hosts if the PMCs were ejected. While some PMC hosts are binaries (including FW Tau and SR 12), the occurrence rate (Bryan et al., submitted) is not higher than for the broader populations of nearby star-forming regions (e.g., Kraus et al. 2011).

4 The Nature and Future Utility of Wide-Orbit PMCs

The demographic results of Ireland et al. (2011) and Lafreniere et al. (2014) demonstrate that PMCs are indeed a standard outcome of star and planet formation, even if none of the current models for their formation seem satisfactory. Indeed, their nature as an extreme outcome makes PMC occurrence an exceptionally strong test for star and planet formation; any model that does not produce objects with $a > 100$ AU and $q \sim 0.01$ is not complete. The nature of this incompleteness will be clarified by robust population statistics. If the PMC mass function is a continuous extension of the stellar binary mass function, then the models resembling binary formation would gain credence as the dominant formation channel. A key observational prediction would be for companions with $M < 20M_{Jup}$ to be outnumbered 3:1 by $20 < M < 80M_{Jup}$ companions, an imbalance that has not yet emerged from the statistics (Lafreniere et al. 2014). Furthermore, if the PMC semimajor axis distribution extends out to $a > 10^3$ AU, as suggested by Kuzuhara et al. (2011) and Aller et al. (2013), then formation during free-fall collapse would be strongly preferred. Finally, a larger sample of orbital arcs (e.g., Ginski et al. 2014; Bryan et al., submitted) could be analyzed on a statistical basis to demonstrate if there is an excess of purely radial motions denoting ejected objects.

PMCs also are more broadly relevant as analogs to traditional planets like HR 8799 bcde (Marois et al. 2008), Beta Pic b (Lagrange et al. 2009), GJ 504 b (Kuzuhara et al. 2013), and HD 95086 b (Rameau et al. 2013), in particular serving as contemporaneous analogs to close-in giant planets like LkCa15 b (Kraus & Ireland 2012; Sallum et al. 2015). PMCs' orbits are very different from Solar System and RV/transiting planets, so it is unclear if they form via similar processes. However, if they form in disks via the same process as bona fide "planets", then PMCs are a boon for exoplanet studies; their wide orbits make them easier observing targets, so they are the high-S/N templates for interpreting difficult observations of traditional planets. Given their wide orbital radii, these accreting PMCs also represent an invaluable resource; these objects provide snapshots of the planet assembly process that can be studied in much more detail than for shorter-period protoplanets like LkCa15 b. The ongoing assembly of wide PMCs provides valuable insight into their provenance, and a glimpse at ongoing giant planet formation processes that have heretofore been unobservable.

References:

Ahmic, M. et al. 2007, ApJ, 671, 2074
Aller, K. et al. 2013, ApJ,773, 63
Allers, K. & Liu, M. 2013, ApJ, 772, 79
Andrews, S. et al. 2013, ApJ, 771, 129
Bailey, V. et al. 2013, ApJ, 767, 31
Bate, M. 2005, MNRAS, 363, 363
Biller, B. et al. 2011, ApJ, 730, 39
Bodenheimer, P. & Burkert, A. 2001, IAUS 200, 13
Bonnefoy, M. et al. 2014, A&A, 562, 127
Boss, A. 1988, ApJ, 331, 370
Boss, A. 2011, ApJ, 731, 74
Bouy, H. et al. 2003, AJ, 126, 1526
Bowler, B. et al. 2011, ApJ, 743, 148
Bowler, B. et al. 2014, ApJ, 784, 65
Bowler, B. et al. 2015, ApJ, 805, 17
Burgasser, A. et al. 2003, ApJ, 586, 512
Caeres, C. et al. 2015, ApJ, 806, 22
Chauvin, G. et al. 2004, A&A, 425, 29
Dodson-Robinson, S. et al. 2009, ApJ, 707, 79
Dupuy, T. & Liu, M. 2012, ApJS, 201, 19
Ginski, C. et al. 2014, Herczeg, G. et al. 2009, ApJ, 696, 1589
Ireland, M. et al. 2011, ApJ, 726, 113
Itoh, Y. et al. 2005, ApJ, 620, 984
Kirkpatrick, J.D. et al. 2008, ApJ, 689, 1295
Kratter, K. et al. 2010, ApJ, 710, 1375
Kraus, A. et al. 2005, ApJ, 633, 452
Kraus, A. et al. 2006, ApJ, 649, 306
Kraus, A. et al. 2011, ApJ, 731, 8
Kraus, A. & Ireland, M. 2012, ApJ, 745, 5
Kraus, A. & Hillenbrand, L. 2012, ApJ, 757, 141
Kraus, A. et al. 2014, ApJ, 781, 20
Kraus, A. et al. 2015, ApJ, 798, 23
Kuzuhara, M. et al. 2011, AJ, 141, 119
Kuzuhara, M. et al. 2013, ApJ, 774, 11
Lachapelle, F.-R. et al. 2015, ApJ, 802, 61
Lafreniere, D. et al. 2008b, ApJ, 689, 153
Lafreniere, D. et al. 2008a, ApJ, 683, 844
Lafreniere, D. et al. 2014, ApJ, 785, 47
Lagrange, A.-M. et al. 2009, A&A, 493, 21
Low, F. & Lynden-Bell, D. 1976, MNRAS, 176, 367
Macintosh, B. et al. 2015, Science, 350, 64
Marois, C. et al. 2008, Science, 322, 1348
McElwain, M. et al. 2007, ApJ, 656, 505
Metchev, S. & Hillenbrand, L. 2009, ApJS, 181, 62
Nakajima, T. et al. 1995, Nature, 378, 463
Nauhäuser, R. et al. 2005, A&A, 435, 13
Pollack, J. et al. 1996, Icarus, 124, 62
Rafikov, R. 2011, ApJ, 727, 86
Raghavan, D. et al. 2010, ApJS, 190, 1
Rameau, J. et al. 2013, ApJ, 772, 15
Ratzka, T. et al. 2005, A&A, 437, 611
Reipurth, B. & Clarke, C. 2001, AJ, 122, 432
Sallum, S. et al. 2015, Nature, 527, 342
Sartoretti, P. et al. 1998, A&A, 334, 592
Schmidt, T. et al. 2008, A&A, 491, 311
Seifahrt, A. et al. 2007, A&A, 463, 309
Stamatellos, D. & Whitworth, A. 2009, MNRAS, 392, 413
Todorov, K. et al. 2014, ApJ, 788, 40
Tomida, K. et al. 2013, ApJ, 763, 6
Toomre, A. 1964, ApJ, 139, 1217
Veras, D. & Armitage, P. 2004, MNRAS, 347, 613
Vorobyov, E. 2013, A&A, 552, 129
Zhou, Y. et al. 2014, ApJ, 783, 17

Abstracts of recently accepted papers

GMRT detections of low mass young stars at 323 and 608 MHz

Rachael E. Ainsworth[1], Anna M. M. Scaife[2], David A. Green[3], Colm P. Coughlan[1] and Tom P. Ray[1]

[1] Dublin Institute for Advanced Studies, School of Cosmic Physics, 31 Fitzwilliam Place, Dublin D02 XF86, Ireland
[2] Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, The University of Manchester, Oxford Road, Manchester M13 9PL, UK
[3] Astrophysics Group, Cavendish Laboratory, J J Thomson Avenue, Cambridge, CB3 0HE

E-mail contact: rainsworth *at* cp.dias.ie

We present the results of a pathfinder project conducted with the Giant Metrewave Radio Telescope (GMRT) to investigate protostellar systems at low radio frequencies. The goal of these investigations is to locate the break in the free-free spectrum where the optical depth equals unity in order to constrain physical parameters of these systems, such as the mass of the ionised gas surrounding these young stars. We detect all three target sources, L1551 IRS 5 (Class I), T Tau and DG Tau (Class II), at frequencies 323 and 608 MHz (wavelengths 90 and 50 cm, respectively). These are the first detections of low mass young stellar objects (YSOs) at such low frequencies. We combine these new GMRT data with archival information to construct the spectral energy distributions for each system and find a continuation of the optically thin free-free spectra extrapolated from higher radio frequencies to 323 MHz for each target. We use these results to place limits on the masses of the ionised gas and average electron densities associated with these young systems on scales of 1000 au. Future observations with higher angular resolution at lower frequencies are required to constrain these physical parameters further.

Accepted by MNRAS

http://arxiv.org/pdf/1603.06836v1.pdf

Ringed Substructure and a Gap at 1 AU in the Nearest Protoplanetary Disk

Sean M. Andrews[1], David J. Wilner[1], Zhaohuan Zhu[2], Tilman Birnstiel[3], John M. Carpenter[4], Laura M. Pérez[5], Xue-Ning Bai[1], Karin I. Öberg[1], A. Meredith Hughes[6], Andrea Isella[7] and Luca Ricci[1]

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA USA
[2] Department of Astrophysical Sciences, Princeton University, 4 Ivy Lane, Peyton Hall, Princeton, NJ 08544, USA
[3] Max-Planck-Institut fr Astronomie, Knigstuhl 17, D-69117 Heidelberg, Germany
[4] Joint ALMA Observatory (JAO), Alonso de Cordova 3107, Vitacura-Santiago de Chile, Chile
[5] Max-Planck-Institut fr Radioastronomie, Auf dem Hgel 69, D-53121 Bonn, Germany
[6] Department of Astronomy, Wesleyan University, Van Vleck Observatory, 96 Foss Hill Drive, Middletown, CT 06457, USA
[7] Department of Physics and Astronomy, Rice University, 6100 Main Street, Houston, TX 77005, USA

E-mail contact: sandrews *at* cfa.harvard.edu

We present long baseline Atacama Large Millimeter/submillimeter Array (ALMA) observations of the 870 μm continuum emission from the nearest gas-rich protoplanetary disk, around TW Hya, that trace millimeter-sized particles down to spatial scales as small as 1 au (20 mas). These data reveal a series of concentric ring-shaped substructures in the form of bright zones and narrow dark annuli (1-6 au) with modest contrasts (5%-30%). We associate these features with concentrations of solids that have had their inward radial drift slowed or stopped, presumably at local gas pressure maxima. No significant non-axisymmetric structures are detected. Some of the observed features occur near temperatures that may be associated with the condensation fronts of major volatile species, but the relatively small brightness contrasts may also be a consequence of magnetized disk evolution (the so-called zonal flows). Other features, particularly a narrow dark annulus located only 1 au from the star, could indicate interactions between the disk and young planets. These data signal that ordered substructures on ∼au scales can be common, fundamental

factors in disk evolution and that high-resolution microwave imaging can help characterize them during the epoch of planet formation.

Accepted by ApJ Letters

http://adsabs.harvard.edu/pdf/2016ApJ...820L..40A
http://arxiv.org/pdf/1603.09352

Detection of protonated formaldehyde in the prestellar core L1689B

A. Bacmann[1,2], E. Garca-García[1,2], and A. Faure[1,2]

[1] Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France
[2] CNRS, IPAG, F-38000 Grenoble, France

E-mail contact: aurore.bacmann *at* univ-grenoble-alpes.fr

Complex organic molecules (COMs) are detected in many regions of the interstellar medium, including prestellar cores. However, their formation mechanisms in cold (~10 K) cores remain to this date poorly understood. The formyl radical HCO is an important candidate precursor for several O-bearing terrestrial COMs in cores, as an abundant building block of many of these molecules. Several chemical routes have been proposed to account for its formation, both on grain surfaces, as an incompletely hydrogenated product of H addition to frozen-out CO molecules, or in the gas phase, either the product of the reaction between H_2CO and a radical, or as a product of dissociative recombination of protonated formaldehyde H_2COH^+. The detection and abundance determination of H_2COH^+, if present, could provide clues as to whether this latter scenario might apply. We searched for protonated formaldehyde H_2COH^+ in the prestellar core L1689B using the IRAM 30m telescope. The H_2COH^+ ion is unambiguously detected, for the first time in a cold (~10 K) source. The derived abundance agrees with a scenario in which the formation of H_2COH^+ results from the protonation of formaldehyde. We use this abundance value to constrain the branching ratio of the dissociative recombination of H_2COH^+ towards the HCO channel to ~10–30%. This value could however be smaller if HCO can be efficiently formed from gas-phase neutral-neutral reactions, and we stress the need for laboratory measurements of the rate constants of these reactions at 10 K. Given the experimental difficulties in measuring branching ratios experimentally, observations can bring valuable constraints on these values, and provide a useful input for chemical networks.

Accepted by A&A Letters

http://arxiv.org/pdf/1603.00477

Towards a Global Evolutionary Model of Protoplanetary Disks

Xue-Ning Bai[1]

[1] Institute for Theory and Computation, Harvard-Smithsonian Center for Astrophysics, 60 Garden St., MS-51, Cambridge, MA 02138, USA

E-mail contact: xbai *at* cfa.harvard.edu

A global evolution picture of protoplanetary disks (PPDs) is key to understanding almost every aspect of planet formation, where standard α-disk models have been constantly employed for its simplicity. In the mean time, disk mass loss has been conventionally attributed to photoevaporation, which controls disk dispersal. However, a paradigm shift towards accretion driven by magnetized disk winds has been realized in the recent years, thanks to studies of non-ideal magneto-hydrodynamic effects in PPDs. I present a framework of global PPD evolution aiming to incorporate these advances, highlighting the role of wind-driven accretion and wind mass loss. Disk evolution is found to be largely dominated by wind-driven processes, and viscous spreading is suppressed. The timescale of disk evolution is controlled primarily by the amount of external magnetic flux threading the disks, and how rapidly the disk loses the flux. Rapid disk dispersal can be achieved if the disk is able to hold most of its magnetic flux during the evolution. In addition, because wind launching requires sufficient level of ionization at disk surface (mainly via external far-UV radiation), wind kinematics is also affected by far-UV penetration depth and disk geometry. For typical disk lifetime of a few Myrs, the disk loses approximately the same amount of mass through the wind as through accretion onto the protostar, and most of the wind mass loss proceeds from the outer disk via a slow wind. Fractional wind mass loss increases with increasing disk lifetime. Significant wind mass loss likely substantially enhances the dust to gas mass

ratio, and promotes planet formation.

Accepted by ApJ

http://arxiv.org/pdf/1603.00484

Trapping planets in an evolving protoplanetary disk: preferred time, locations and planet mass

K. Baillié[1,2,3], S. Charnoz[2,3], and E. Pantin[3]

[1] IMCCE, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC, Univ. Lille 1, 77 Av. DenfertRochereau, 75014 Paris, France

[2] Institut de Physique du Globe, Sorbonne Paris Cité, Université Paris Diderot/CNRS, 1 rue Jussieu, 75005 Paris, France

[3] Laboratoire AIM-LADP, Université Paris Diderot/CEA/CNRS, 91191 Gif sur Yvette, France

E-mail contact: kevin.baillie *at* obspm.fr

Planet traps are necessary to prevent forming planets from falling onto their host star by type I migration. Surface mass density and temperature gradient irregularities favor the apparition of traps and deserts. Such features are found at the dust sublimation lines and heat transition barriers. We study how planets may remain trapped or escape as they grow and as the disk evolves. We model the temporal viscous evolution of a protoplanetary disk by coupling its dynamics, thermodynamics, geometry and composition. The resulting mid-plane density and temperature profiles allow the modeling of the interactions of such an evolving disk with potential planets, even before the steady state is reached. We follow the viscous evolution of a MMSN and compute the Lindblad and corotation torques that such a disk would exert on potential planets of various masses located within the planetary formation region. We determine the position of planet traps and deserts in relationship with the sublimation lines, shadowed regions and heat transition barriers. Planets that are a few tens of Earth masses can be trapped at the sublimation lines until they reach a certain mass while planets more massive than 100 $M_\oplus$ can only be trapped permanently at the heat transition barriers. Coupling a bimodal planetary migration model with a self-consistent evolved disk, we were able to distinguish several potential planet populations after 5 million years of evolution: two populations of giant planets that could stay trapped around 5.5 and 9 au and possibly open gaps, some super-Earths trapped around 5 and 7.5 au and a population of close-in super-Earths trapped inside 1 au. The traps corresponding to the last group could help validating the in-situ formation scenarios of the observed close-in super-Earths.

Accepted by A&A

http://arxiv.org/pdf/1603.07674

WISH VI. Constraints on UV and X-ray irradiation from a survey of hydrides in low- to high-mass YSOs

A. O. Benz[1], S. Bruderer[1,2], E. F. van Dishoeck[2,3], M. Melchior[1,4], S. F. Wampfler[1,5], F. van der Tak[6,7], J. R. Goicoechea[8], N. Indriolo[9], L. E. Kristensen[10], D.C. Lis[11,12], J. C. Mottram[3,22], E. A. Bergin[9], P. Caselli[2], F. Herpin[13,14], M. R. Hogerheijde[3], D. Johnstone[15,16], R. Liseau[17], B. Nisini[18], M. Tafalla[19], R. Visser[20] and F. Wyrowski[21]

[1] Institute for Astronomy, ETH Zurich, 8093 Zurich, Switzerland

[2] Max-Planck-Institut für extraterrestrische Physik, Giessenbachstrasse 1, 85748 Garching, Germany

[3] Leiden Observatory, Leiden University, PO Box 9513, 2300 RA Leiden, The Netherlands

[4] Institute of 4D Technologies, University of Applied Sciences FHNW, CH-5210 Windisch, Switzerland

[5] Centre for Star and Planet Formation, Natural History Museum of Denmark, and Niels Bohr Institute, Oster Voldgade 5-7, DK-1350 Copenhagen K., Denmark

[6] SRON Netherlands Institute for Space Research, PO Box 800, 9700 AV, Groningen, The Netherlands

[7] Kapteyn Astronomical Institute, University of Groningen, PO Box 800, 9700 AV, Groningen, The Netherlands

[8] Grupo de Astrofisica Molecular, Instituto de Ciencia de Materiales de Madrid (ICMM), Consejo Superior de Investigaciones Cientificas (CSIC), Calle Sor Juana Ines de la Cruz, 3, E-28049 Cantoblanco, Madrid, Spain

[9] Department of Astronomy, The University of Michigan, 1085 S. University Ave., Ann Arbor, MI 48109-1107, USA

[10] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA, 02138, USA
[11] LERMA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universites, UPMC Univ. Paris 06, F-75014, Paris, France
[12] California Institute of Technology, Cahill Center for Astronomy and Astrophysics, MS 301-17, Pasadena, CA 91125, USA
[13] Univ. Bordeaux, LAB, UMR 5804, F-33270, Floirac, France
[14] CNRS, LAB, UMR 5804, F-33270, Floirac, France
[15] National Research Council Canada, Herzberg Astronomy and Astrophysics, 5071 West Saanich Rd, Victoria, BC, V9E 2E7, Canada
[16] Department of Physics & Astronomy, University of Victoria, Victoria, BC, V8P 1A1, Canada
[17] Department of Radio and Space Science, Chalmers University of Technology, Onsala Space Observatory, 439 92 Onsala, Sweden
[18] INAF - Osservatorio Astronomico di Roma, 00040 Monte Porzio catone, Italy
[19] Observatorio Astronómico Nacional (IGN), Calle Alfonso XII,3. 28014, Madrid, Spain
[20] European Southern Observatory, Karl-Schwarzschild-Strasse 2, D-85748, Garching, Germany
[21] Max-Planck-Institut fur Radioastronomie, Auf dem Hugel 69, 53121 Bonn, Germany
[22] Max Planck Institute for Astronomy, Konigstuhl 17, 69117 Heidelberg, Germany

E-mail contact: benz *at* astro.phys.ethz.ch

Hydrides are simple compounds containing one or a few hydrogen atoms bonded to a heavier atom. They are fundamental precursor molecules in cosmic chemistry and many hydride ions have become observable in high quality for the first time thanks to the *Herschel Space Observatory*. Ionized hydrides, such as CH^+ and OH^+, and also HCO^+ that affect the chemistry of molecules such as water, provide complementary information on irradiation by far UV (FUV) or X-rays and gas temperature.
We explore hydrides of the most abundant heavier elements in an observational survey covering young stellar objects (YSO) with different mass and evolutionary state. The focus is on hydrides associated with the dense protostellar envelope and outflows, contrary to previous work that focused on hydrides in diffuse foreground clouds.
Twelve YSOs were observed with HIFI on *Herschel* in 6 spectral settings providing fully velocity-resolved line profiles as part of the 'Water in star-forming regions with *Herschel*' (WISH) program. The YSOs include objects of low (Class 0 and I), intermediate, and high mass, with luminosities ranging from 4 $L_\odot$ to 2×10^5 $L_\odot$.
The targeted lines of CH^+, OH^+, H_2O^+, C^+ and CH are detected mostly in blue-shifted absorption. H_3O^+ and SH^+ are detected in emission and only toward some high-mass objects. The observed line parameters and correlations suggest two different origins, related to gas entrained by the outflows and to the circumstellar envelope. The derived column densities correlate with bolometric luminosity and envelope mass for all molecules, best for CH, CH^+, and HCO^+. The column density ratios of CH^+/OH^+ are estimated from chemical slab models, assuming that the H_2 density is given by the specific density model of each object at the beam radius. For the low-mass YSOs the observed ratio can be reproduced for an FUV flux of 2 – 400 times the ISRF at the location of the molecules. In two high-mass objects, the UV flux is 20 – 200 times the ISRF derived from absorption lines, and 300 – 600 ISRF using emission lines. Upper limits for the X-ray luminosity can be derived from H_3O^+ observations for some low-mass objects.
If the FUV flux required for low-mass objects originates at the central protostar, a substantial FUV luminosity, up to 1.5 $L_\odot$, is required. There is no molecular evidence for X-ray induced chemistry in the low-mass objects on the observed scales of a few 1000 AU. For high-mass regions, the FUV flux required to produce the observed molecular ratios is smaller than the unattenuated flux expected from the central object(s) at the *Herschel* beam radius. This is consistent with an FUV flux reduced by circumstellar extinction or by bloating of the protostar.

Accepted by Astronomy and Astrophysics

http://arxiv.org/pdf/1603.08721

Isotopic ratios of H, C, N, O, and S in comets C/2012 F6 (Lemmon) and C/2014 Q2 (Lovejoy)

N. Biver[1], [1], R. Moreno[1], D. Bockelée-Morvan[1], Aa. Sandqvist[2], P. Colom[1], J. Crovisier[1], D.C. Lis[3], J. Boissier[4], V. Debout[1], G. Paubert[5], S. Milam[6], Å. Hjalmarson[7], S. Lundin[8], T. Karlsson[8], M. Battelino[8], U. Frisk[9], D. Murtagh[10] and the Odin team

[1] LESIA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, Univ. Paris Diderot, Sorbonne Paris Cité, 5 place Jules Janssen, F-92195 Meudon, France
[2] Stockholm Observatory, AlbaNova University Center, SE-106 91 Stockholm, Sweden
[3] LERMA, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, F-75014, Paris, France
[4] IRAM, 300, rue de la Piscine, F-38406 Saint Martin d'Hères, France
[5] IRAM, Avd. Divina Pastora, 7, 18012 Granada, Spain
[6] NASA Goddard Space Flight Center, Astrochemistry Laboratory, Code 691.0, Greenbelt, MD 20771, USA
[7] Onsala Space Observatory, Chalmers University of Technology, SE-439 92 ONSALA, Sweden
[8] OHB Sweden, P.O. Box 1269, SE-164 29 Kista, Sweden
[9] Omnisys Instruments, August Barks Gata 6B, SE-421 32 Västra Frölunda, Sweden
[10] Dept. of Radio and Space Science, Chalmers Technical University, Gothenburg, Sweden

E-mail contact: Nicolas.Biver *at* obspm.fr

The apparition of bright comets C/2012 F6 (Lemmon) and C/2014 Q2 (Lovejoy) in March-April 2013 and January 2015, combined with the improved observational capabilities of submillimeter facilities, offered an opportunity to carry out sensitive compositional and isotopic studies of the volatiles in their coma. We observed comet Lovejoy with the IRAM 30m telescope between 13 and 26 January 2015, and with the Odin submillimeter space observatory on 29 January - 3 February 2015. We detected 22 molecules and several isotopologues. The $H_2^{16}O$ and $H_2^{18}O$ production rates measured with Odin follow a periodic pattern with a period of 0.94 days and an amplitude of ~25%. The inferred isotope ratios in comet Lovejoy are $^{16}O/^{18}O=499 \pm 24$ and D/H $=1.4 \pm 0.4 \times 10^{-4}$ in water, $^{32}S/^{34}S = 24.7 \pm 3.5$ in CS, all compatible with terrestrial values. The ratio $^{12}C/^{13}C = 109 \pm 14$ in HCN is marginally higher than terrestrial and $^{14}N/^{15}N = 145 \pm 12$ in HCN is half the Earth ratio. Several upper limits for D/H or $^{12}C/^{13}C$ in other molecules are reported. From our observation of HDO in comet C/2014 Q2 (Lovejoy), we report the first D/H ratio in an Oort Cloud comet that is not larger than the terrestrial value. On the other hand, the observation of the same HDO line in the other Oort-cloud comet, C/2012 F6 (Lemmon), suggests a D/H value four times higher. Given the previous measurements of D/H in cometary water, this illustrates that a diversity in the D/H ratio and in the chemical composition, is present even within the same dynamical group of comets, suggesting that current dynamical groups contain comets formed at very different places or times in the early solar system.

Accepted by A&A

http://www.aanda.org/articles/aa/pdf/forth/aa28041-15.pdf

Resolving the Planetesimal Belt of HR 8799 with ALMA

Mark Booth[1,2], Andrés Jordán[1,3], Simon Casassus[2,4], Antonio S. Hales[5,6], William R. F. Dent[5], Virginie Faramaz[1], Luca Matrà[7,8], Denis Barkats[9], Rafael Brahm[1,3] and Jorge Cuadra[1,2]

[1] Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Santiago, Chile
[2] Millennium Nucleus "Protoplanetary Disks", Santiago, Chile
[3] Millennium Institute of Astrophysics, Vicuña Mackenna 4860, Santiago, Chile
[4] Departamento de Astronomia, Universidad de Chile, Casilla 36-D, Santiago, Chile
[5] Joint ALMA Observatory, Alonso de Córdova 3107, Vitacura 763-0355, Santiago, Chile
[6] National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, Virginia, 22903-2475, USA
[7] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK
[8] European Southern Observatory, Alonso de Córdova 3107, Vitacura, Casilla 19001, Santiago, Chile
[9] Harvard University, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: markbooth@cantab.net

The star HR 8799 hosts one of the largest known debris discs and at least four giant planets. Previous observations have found evidence for a warm belt within the orbits of the planets, a cold planetesimal belt beyond their orbits and a halo of small grains. With the infrared data, it is hard to distinguish the planetesimal belt emission from that of the grains in the halo. With this in mind, the system has been observed with ALMA in band 6 (1.34 mm) using a compact array format. These observations allow the inner edge of the planetesimal belt to be resolved for the first time. A radial distribution of dust grains is fitted to the data using an MCMC method. The disc is best fit by a broad ring between 145^{+12}_{-12} AU and 429^{+37}_{-32} AU at an inclination of $40^{+5}_{-6}{}^\circ$ and a position angle of $51^{+8}_{-8}{}^\circ$. A disc edge

at ∼145 AU is too far out to be explained simply by interactions with planet b, requiring either a more complicated dynamical history or an extra planet beyond the orbit of planet b.

Accepted by MNRAS

http://dx.doi.org/10.1093/mnrasl/slw040
http://arxiv.org/pdf/1603.4853

Collision velocity of dust grains in self-gravitating protoplanetary discs

Richard A. Booth[1], Cathie J. Clarke[1]

[1] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, United Kingdom

E-mail contact: rab200 *at* ast.cam.ac.uk

We have conducted the first comprehensive numerical investigation of the relative velocity distribution of dust particles in self-gravitating protoplanetary discs with a view to assessing the viability of planetesimal formation via direct collapse in such environments. The viability depends crucially on the large sizes that are preferentially collected in pressure maxima produced by transient spiral features (Stokes numbers, $St \sim 1$); growth to these size scales requires that collision velocities remain low enough that grain growth is not reversed by fragmentation. We show that, for a single sized dust population, velocity driving by the disc's gravitational perturbations is only effective for $St > 3$, while coupling to the gas velocity dominates otherwise. We develop a criterion for understanding this result in terms of the stopping distance being of order the disc scale height. Nevertheless, the relative velocities induced by differential radial drift in multi-sized dust populations are too high to allow the growth of silicate dust particles beyond $St \sim 10^{-2}$ or 10^{-1} (10 cm to m sizes at 30 AU), such Stokes numbers being insufficient to allow concentration of solids in spiral features. However, for icy solids (which may survive collisions up to several 10 m s^{-1}), growth to $St \sim 1$ (10 m size) may be possible beyond 30 AU from the star. Such objects would be concentrated in spiral features and could potentially produce larger icy planetesimals/comets by gravitational collapse. These planetesimals would acquire moderate eccentricities and remain unmodified over the remaining lifetime of the disc.

Accepted by MNRAS

http://arxiv.org/pdf/1603.00029

Analysis of terrestrial planet formation by the Grand Tack model: System architecture and tack location

R. Brasser[1], S. Matsumura[2], S. Ida[1], S.J. Mojzsis[3,4], S.C. Werner[5]

[1] Earth-Life Science Institute, Tokyo Institute of Technology, Meguro-ku, Tokyo 152-8550, Japan

[2] School of Science and Engineering, Division of Physics, Fulton Building, University of Dundee, Dundee DD1 4HN, UK

[3] Collaborative for Research in Origins (CRiO), Department of Geological Sciences, University of Colorado, UCB 399, 2200 Colorado Avenue, Boulder, Colorado 80309-0399, USA

[4] Institute for Geological and Geochemical Research, Research Center for Astronomy and Earth Sciences, Hungarian Academy of Sciences, 45 Budaörsi Street, H-1112 Budapest, Hungary

[5] The Centre for Earth Evolution and Dynamics, University of Oslo, Sem Saelandsvei 24, 0371 Oslo, Norway

E-mail contact: brasser_astro *at* yahoo.com

The Grand Tack model of terrestrial planet formation has emerged in recent years as the premier scenario used to account for several observed features of the inner solar system. It relies on early migration of the giant planets to gravitationally sculpt and mix the planetesimal disc down to ∼1 AU, after which the terrestrial planets accrete from material left in a narrow circum-solar annulus. Here we have investigated how the model fares under a range of initial conditions and migration course-change ('tack') locations. We have run a large number of N-body simulations with a tack location of 1.5 AU and 2 AU and tested initial conditions using equal mass planetary embryos and a semi-analytical approach to oligarchic growth. We make use of a recent model of the protosolar disc that takes account of viscous heating, include the full effect of type 1 migration, and employ a realistic mass-radius relation for the growing terrestrial planets. Results show that the canonical tack location of Jupiter at 1.5 AU is inconsistent with the most massive planet residing at 1 AU at greater than 95% confidence. This favours a tack farther out at 2 AU for the

disc model and parameters employed. Of the different initial conditions, we find that the oligarchic case is capable of statistically reproducing the orbital architecture and mass distribution of the terrestrial planets, while the equal mass embryo case is not.

Accepted by ApJ

http://arxiv.org/pdf/1603.01009

Tracing jet emission at the base of a high-mass YSO. First AMBER/VLTI observations of the Brγ emission in IRAS 13481-6124

A. Caratti o Garatti[1], B. Stecklum[2], G. Weigelt[3], D. Schertl[3], K.-H. Hofmann[3], S. Kraus[4], R.D. Oudmaijer[5], W.J. de Wit[6], A. Sanna[3], R. Garcia Lopez[1], A. Kreplin[4] and T.P. Ray[1]

[1] Dublin Institute for Advanced Studies, Ireland
[2] Thüringer Landessternwarte Tautenburg, Germany
[3] Max-Planck-Institut für Radioastronomie, Germany
[4] University of Exeter, School of Physics, UK
[5] School of Physics and Astronomy, University of Leeds, UK
[6] ESO, Germany

E-mail contact: alessio *at* cp.dias.ie

Aims. To probe the circumstellar environment of IRAS 13481-6124, a 20 $M_\odot$ high-mass young stellar object (HMYSO) with a collimated parsec-scale jet and an accretion disc, we investigate the origin of its Brγ emission line through NIR interferometry.
Methods. We present the first AMBER/VLTI observations of the Brγ emitting region in an HMYSO at medium spectral resolution (R=1500).
Results. Our AMBER/VLTI observations reveal a spatially and spectrally resolved Brγ line in emission with a strong P Cygni profile, indicating outflowing matter with a terminal velocity of $\sim$500 km s^{-1}. Visibilities, differential phases, and closure phases are detected in our observations within the spectral line and in the adjacent continuum. Both total visibilities (continuum plus line emitting region) and pure-line visibilities indicate that the Brγ-emitting region is more compact (2–4 mas in diameter or $\sim$6–13 au at 3.2 kpc) than the continuum-emitting region ($\sim$5.4 mas or $\sim$17 au). The absorption feature is also spatially resolved at the longest baselines (81 and 85 m) and has a visibility that is slightly smaller than the continuum-emitting region. The differential phases at the four longest baselines display an 'S'-shaped structure across the line, peaking in the blue- and red-shifted high-velocity components. The calibrated photocentre shifts are aligned with the known jet axis, i.e they are probably tracing an ionised jet. The high-velocity components ($v_r$$\sim$100–500 km s^{-1}) are located far from the source, whereas the low-velocity components (0–100 km s^{-1}) are observed to be closer, indicating a strong acceleration of the gas flow in the inner 10 au. Finally, a non-zero closure phase along the continuum is detected. By comparing our observations with the synthetic images of the continuum around 2.16 μm, we confirm that this feature originates from the asymmetric brightness distribution of the continuum owing to the inclination of the inner disc.

Accepted by A&A Letters

http://arxiv.org/pdf/1603.06860

The VLA view of the HL Tau Disk - Disk Mass, Grain Evolution, and Early Planet Formation

Carlos Carrasco-González[1], Thomas Henning[2], Claire J. Chandler[3], Hendrik Linz[2], Laura Pérez[4], Luis F. Rodr'{ıguez[1], Roberto Galván-Madrid[1], Guillem Anglada[5], Til Birnstiel[2], Roy van Boekel[2], Mario Flock[6], Hubert Klahr[2], Enrique Macías[5], Karl Menten[4], Mayra Osorio[5], Leonardo Testi[7], José M. Torrelles[8] and Zhaohuan Zhu[9]

[1] Instituto de Radioastronomía y Astrofísica (IRyA), México
[2] Max-Planck-Institut fuer Astronomie Heidelberg, Germany
[3] National Radio Astronomy Observatory, USA
[4] Max-Planck-Institut fuer Radioastronomie, Germany

[5] Instituto de Astrofísica de Andalucía (IAA-CSIC), Spain
[6] Jet Propulsion Laboratory, California Institute of Technology, USA
[7] European Southern Observatory, Germany
[8] Institut de Ciències de l'Espai (CSIC-IEEC), Spain
[9] INAF-Osservatorio Astrofisico di Arcetri, Italy

E-mail contact: carrasco *at* crya.unam.mx

The first long-baseline ALMA campaign resolved the disk around the young star HL Tau into a number of axisymmetric bright and dark rings. Despite the very young age of HL Tau these structures have been interpreted as signatures for the presence of (proto)planets. The ALMA images triggered numerous theoretical studies based on disk-planet interactions, magnetically driven disk structures, and grain evolution. Of special interest are the inner parts of disks, where terrestrial planets are expected to form. However, the emission from these regions in HL Tau turned out to be optically thick at all ALMA wavelengths, preventing the derivation of surface density profiles and grain size distributions. Here, we present the most sensitive images of HL Tau obtained to date with the Karl G. Jansky Very Large Array at 7.0 mm wavelength with a spatial resolution comparable to the ALMA images. At this long wavelength the dust emission from HL Tau is optically thin, allowing a comprehensive study of the inner disk. We obtain a total disk dust mass of (1-3)$\times10^{-3}$ M$_\odot$, depending on the assumed opacity and disk temperature. Our optically thin data also indicate fast grain growth, fragmentation, and formation of dense clumps in the inner densest parts of the disk. Our results suggest that the HL Tau disk may be actually in a very early stage of planetary formation, with planets not already formed in the gaps but in the process of future formation in the bright rings.

Accepted by The Astrophysical Journal Letters

http://arxiv.org/pdf/1603.03731

A Hot and Massive Accretion Disk around the High-Mass Protostar IRAS 20126+4104

Huei-Ru Vivien Chen[1,2], Eric Keto[3], Qizhou Zhang[3], T. K. Sridharan[3], Sheng-Yuan Liu[2] and Yu-Nung Su[2]

[1] Institute of Astronomy & Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan
[2] Academia Sinica Institute of Astronomy and Astrophysics, Taipei 10617, Taiwan
[3] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02318, USA

E-mail contact: hchen *at* phys.nthu.edu.tw

We present new spectral line observations of the CH_3CN molecule in the accretion disk around the massive protostar IRAS 20126+4104 with the Submillimeter Array that for the first time measure the disk density, temperature, and rotational velocity with sufficient resolution (0.37″, equivalent to $\sim$ 600 AU) to assess the gravitational stability of the disk through the Toomre-Q parameter. Our observations resolve the central 2000 AU region that shows steeper velocity gradients with increasing upper state energy, indicating an increase in the rotational velocity of the hotter gas nearer the star. Such spin-up motions are characteristics of an accretion flow in a rotationally supported disk. We compare the observed data with synthetic image cubes produced by three-dimensional radiative transfer models describing a thin flared disk in Keplerian motion enveloped within the centrifugal radius of an angular-momentum-conserving accretion flow. Given a luminosity of $1.3 \times 10^4\ L_\odot$, the optimized model gives a disk mass of 1.5 $M_\odot$ and a radius of 858 AU rotating about a 12.0 $M_\odot$ protostar with a disk mass accretion rate of $3.9 \times 10^{-5}\ M_\odot\,\mathrm{yr}^{-1}$. Our study finds that, in contrast to some theoretical expectations, the disk is hot and stable to fragmentation with $Q > 2.8$ at all radii, which permits a smooth accretion flow. These results put forward the first constraints on gravitational instabilities in massive protostellar disks, which are closely connected to the formation of companion stars and planetary systems by fragmentation.

Accepted by The Astrophysical Journal

http://arxiv.org/pdf/1604.00523

Coeval intermediate-mass star formation in N4W

Zhiwei Chen[1], Shaobo Zhang[1], Miaomiao Zhang[1], Zhibo Jiang[1], Motohide Tamura[2,3] and Jungmi Kwon[2,3]

[1] Purple Mountain Observatory, 2 West Beijing Road, Nanjing 210008, China
[2] Department of Astronomy, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[3] National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

E-mail contact: zwchen *at* pmo.ac.cn

Protostars are mostly found in star-forming regions, where the natal molecular gas still remains. In about 5' west of the molecular bubble N4, N4W is identified as a star-forming clump hosting three Class II (IRS 1 − 3), and one Class I (IRS 4) young stellar objects (YSOs), as well as a submillimeter source SMM1. The near-IR polarization imaging data of N4W reveal two infrared reflection nebulae close to each other, which are in favor of the outflows of IRS 1 and IRS 2. The bipolar mid-IR emission centered on IRS 4 and the arc-like molecular gas shell are lying on the same axis, indicating a bipolar molecular outflow from IRS 4. There are two dust temperature distributions in N4W. The warmer one is widely distributed and has a temperature $T_{\rm d} \gtrsim 28\,{\rm K}$, with the colder one from the embedded compact submillimeter source SMM1. N4W's mass is estimated to be $\sim 2.5 \times 10^3\,M_\odot$, and the mass of SMM1 is $\sim 5.5 \times 10^2\,M_\odot$ at $T_{\rm d} = 15\,{\rm K}$, calculated from the CO $1-0$ emission and $870\,\mu$m dust continuum emission, respectively. Based on the estimates of bolometric luminosity of IRS 1 − 4, these four sources are intermediate-mass YSOs at least. SMM1 is gravitationally bound, and is capable of forming intermediate-mass stars or even possibly massive stars. The co-existence of the IR bright YSOs and the submillimeter source represents potential sequential star formation processes separated by ~ 0.5 Myr in N4W. This small age spread implies that the intermediate-mass star formation processes happening in N4W are almost coeval.

Accepted by Astrophysical Journal

http://arxiv.org/pdf/1603.08385

Perturbation growth in accreting filaments

S. D. Clarke[1], A. P. Whitworth[1] and D. A. Hubber[2,3]

[1] School of Physics and Astronomy, Cardiff University, Cardiff CF24 3AA, UK
[2] University Observatory Munich, Ludwig-Maximilians-University Munich, Scheinerstr.1, D-81679 Munich, Germany
[3] Excellence Cluster Universe, Boltzmannstr. 2, D-85748 Garching, Germany

E-mail contact: seamus.clarke *at* astro.cf.ac.uk

We use smoothed particle hydrodynamic simulations to investigate the growth of perturbations in infinitely long filaments as they form and grow by accretion. The growth of these perturbations leads to filament fragmentation and the formation of cores. Most previous work on this subject has been confined to the growth and fragmentation of equilibrium filaments and has found that there exists a preferential fragmentation length-scale which is roughly four times the filament's diameter. Our results show a more complicated dispersion relation with a series of peaks linking perturbation wavelength and growth rate. These are due to gravo-acoustic oscillations along the longitudinal axis during the sub-critical phase of growth. The positions of the peaks in growth rate have a strong dependence on both the mass accretion rate onto the filament and the temperature of the gas. When seeded with a multiwavelength density power spectrum, there exists a clear preferred core separation equal to the largest peak in the dispersion relation. Our results allow one to estimate a minimum age for a filament which is breaking up into regularly spaced fragments, as well as an average accretion rate. We apply the model to observations of filaments in Taurus by Tafalla & Hacar and find accretion rates consistent with those estimated by Palmeirim et al.

Accepted by MNRAS

http://arxiv.org/pdf/1602.07651

What can simulated molecular clouds tell us about real molecular clouds?

A. Duarte-Cabral[1] and C. L. Dobbs[1]

[1] School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, U.K.

E-mail contact: adc *at* astro.ex.ac.uk

We study the properties of giant molecular clouds (GMCs) from a smoothed particle hydrodynamics simulation of a portion of a spiral galaxy, modelled at high resolution, with robust representations of the physics of the interstellar

medium. We examine the global molecular gas content of clouds, and investigate the effect of using CO or H2 densities to define the GMCs. We find that CO can reliably trace the high-density H2 gas, but misses less dense H2 clouds. We also investigate the effect of using 3D CO densities versus CO emission with an observers perspective, and find that CO-emission clouds trace well the peaks of the actual GMCs in 3D, but can miss the lower density molecular gas between density peaks which is often CO-dark. Thus, the CO emission typically traces smaller clouds within larger GMC complexes. We also investigate the effect of the galactic environment (in particular the presence of spiral arms), on the distribution of GMC properties, and we find that the mean properties are similar between arm and inter-arm clouds, but the tails of some distributions are indicative of intrinsic differences in the environment. We find highly filamentary clouds (similar to the giant molecular filaments of our Galaxy) exclusively in the inter-arm region, formed by galactic shear. We also find that the most massive GMC complexes are located in the arm, and that as a consequence of more frequent cloud interactions/mergers in the arm, arm clouds are more sub-structured and have higher velocity dispersions than inter-arm clouds.

Accepted by MNRAS

http://arxiv.org/pdf/1603.02470

Structure and stability in TMC-1: analysis of NH_3 molecular line and Herschel continuum data

O. Fehér[1,2], L. V. Tóth[1], D. Ward-Thompson[3], J. Kirk[3], A. Kraus[4], V.-M. Pelkonen[5], S. Pintér[1] and S. Zahorecz[1,6]

[1] Eötvös Loránd University, Department of Astronomy, Pázmány Péter sétány 1/A, 1117 Budapest, Hungary

[2] Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, H-1121 Budapest, Konkoly Thege Miklós út 15-17, Hungary

[3] Jeremiah Horrocks Institute, University of Central Lancashire, Preston PR1 2HE, UK

[4] Max Planck Institute for Radioastronomy, Auf dem Hügel 69, 53121 Bonn, Germany

[5] Department of Physics, PO Box 64, 00014 University of Helsinki, Finland

[6] European Southern Observatory, Karl-Schwarzschild-Str. 2, D-85748, Garching bei München, Germany

E-mail contact: feher.orsolya *at* csfk.mta.hu

Aims. We examined the velocity, density and temperature structure of Taurus Molecular Cloud-1 (TMC-1), a filamentary cloud in a nearby quiescent star forming area, to understand its morphology and evolution.
Methods. We observed high S/N, high velocity resolution $NH_3(1,1)$ and (2,2) emission on an extended map. By fitting multiple hyperfine-split line profiles to the $NH_3(1,1)$ spectra we derived the velocity distribution of the line components and calculated gas parameters on several positions. *Herschel SPIRE* far-infrared continuum observations were reduced and used to calculate the physical parameters of the *Planck* Galactic Cold Clumps (PGCCs) in the region, including the two in TMC-1. The morphology of TMC-1 was investigated with several types of clustering methods in the position-velocity-column density parameter space.
Results. Our *Herschel*-based column density map shows a main ridge with two local maxima and a separated peak to the south-west. H_2-column densities and dust colour temperatures are in the range of $0.5\text{-}3.3\times10^{22}\,\mathrm{cm}^{-2}$ and 10.5-12 K, respectively. NH_3-column densities and H_2-volume densities are in the range of $2.8\text{-}14.2\times10^{14}\,\mathrm{cm}^{-2}$ and $0.4\text{-}2.8\times10^{4}\ \mathrm{cm}^{-3}$. Kinetic temperatures are typically very low with a minimum of 9 K at the maximum NH_3 and H_2-column density region. The kinetic temperature maximum was found at the protostar IRAS 04381+2540 with a value of 13.7 K. The kinetic temperatures vary similarly as the colour temperatures in spite of the fact that densities are lower than the critical density for coupling between the gas and dust phase. The k-means clustering method separated four sub-filaments in TMC-1 with masses of 32.5, 19.6, 28.9 and 45.9 $M_\odot$ and low turbulent velocity dispersion in the range of 0.13-0.2 $\mathrm{km\,s}^{-1}$.
Conclusions. The main ridge of TMC-1 is composed of four sub-filaments that are close to gravitational equilibrium. We label them TMC-1F1 through F4. TMC-1F1, TMC-1F2 and TMC-1F4 are very elongated, dense and cold. TMC-1F3 is a little less elongated and somewhat warmer, probably heated by the Class I protostar, IRAS 04381+2540 that is embedded in it. TMC-1F3 is approximately 0.1 pc behind TMC1-F1. Because of its structure, TMC-1 is a good target to test filament evolution scenarios.

Accepted by Astronomy and Astrophysics

http://arxiv.org/pdf/1603.05844

Are Infrared Dark Clouds Really Quiescent?

S. Feng[1,2], H. Beuther[2], Q. Zhang[3], Th. Henning[2], H. Linz[2], S. Ragan[4] and R. Smith[5]

[1] Max-Planck-Institut fur Extraterrestrische Physik, Germany
[2] Max-Planck-Institut fur Astronomie, Germany
[3] Harvard-Smithsonian Center for Astrophysics, USA
[4] School of Physics and Astronomy, The University of Leeds, UK
[5] Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, University of Manchester, UK

E-mail contact: syfeng *at* mpe.mpg.de

Context: The dense, cold regions where high-mass stars form are poorly characterised, yet they represent an ideal opportunity to learn more about the initial conditions of high-mass star formation (HMSF), since high-mass starless cores (HMSCs) lack the violent feedback seen at later evolutionary stages.
Aims: To investigate the initial conditions of HMSF by studying the dynamics and chemistry of HMSCs.
Methods: We present continuum maps obtained from the Submillimeter Array (SMA) interferometry at 1.1 mm for four infrared dark clouds (IRDCs, G28.34S, IRDC 18530, IRDC 18306, and IRDC 18308). For these clouds, we also present line surveys at 1 mm/3 mm obtained from IRAM 30 m single-dish observations.
Results: (1) At an angular resolution of 2$''$ ($\sim 10^4$ AU at an average distance of 4 kpc), the 1.1 mm SMA observations resolve each source into several fragments. The mass of each fragment is on average $> 10\,M_\odot$, which exceeds the predicted thermal Jeans mass of the whole clump by a factor of up to 60, indicating that thermal pressure does not dominate the fragmentation process. Our measured velocity dispersions in the 30 m lines imply that non-thermal motions provides the extra support against gravity in the fragments. (2) Both non-detection of high-J transitions and the hyperfine multiplet fit of N_2H^+ ($J = 1 \rightarrow 0$), C_2H ($N = 1 \rightarrow 0$), HCN ($J = 1 \rightarrow 0$), and $H^{13}CN$ ($J = 1 \rightarrow 0$), indicate that our sources are cold and young. However, obvious detection of SiO and the asymmetric line profile of HCO^+ ($J = 1 \rightarrow 0$) in G28.34 S indicate a potential protostellar object and probable infall motion. (3) With a large number of N-bearing species, the existence of carbon rings and molecular ions, and the anti-correlated spatial distributions between N_2H^+/NH_2D and CO, our large-scale high-mass clumps exhibit similar chemical features as small-scale low-mass prestellar objects.
Conclusions: This study of a small sample of IRDCs illustrates that thermal Jeans instability alone cannot explain the fragmentation of the clump into cold ($T \sim 15$ K), dense ($> 10^5$ cm^{-3}) cores and that these IRDCs are not completely quiescent.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/1603.04862

The Population of Compact Radio Sources in the Orion Nebula Cluster

Jan Forbrich[1,2], Victor M. Rivilla[3], Karl M. Menten[4], Mark J. Reid[2], Claire J. Chandler[5], Urvashi Rau[5], Sanjay Bhatnagar[5], Scott J. Wolk[2] and Stefan Meingast[1]

[1] University of Vienna, Department of Astrophysics, Türkenschanzstr. 17, 1180 Vienna, Austria
[2] Harvard-Smithsonian Center for Astrophysics, 60 Garden St, Cambridge, MA 02138, USA
[3] Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi, 5, I-50125, Firenze, Italy
[4] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
[5] National Radio Astronomy Observatory, P.O. Box O, Socorro, NM 87801, USA

E-mail contact: jan.forbrich *at* univie.ac.at

We present a deep centimeter-wavelength catalog of the Orion Nebula Cluster (ONC), based on a 30 h single-pointing observation with the Karl G. Jansky Very Large Array in its high-resolution A-configuration using two 1 GHz bands centered at 4.7 GHz and 7.3 GHz. A total of 556 compact sources were detected in a map with a nominal rms noise of 3 μJy bm^{-1}, limited by complex source structure and the primary beam response. Compared to previous catalogs, our detections increase the sample of known compact radio sources in the ONC by more than a factor of seven. The new data show complex emission on a wide range of spatial scales. Following a preliminary correction for the wideband primary-beam response, we determine radio spectral indices for 170 sources whose index uncertainties are less than ± 0.5. We compare the radio to the X-ray and near-infrared point-source populations, noting similarities and differences.

Accepted by Astrophys. J.

http://arxiv.org/pdf/1603.05666

Opacity broadening and interpretation of suprathermal CO linewidths: Macroscopic Turbulence and Tangled Molecular Clouds

A. Hacar[1], J. Alves[1], A. Burkert[2,3] and P. Goldsmith[4]

[1] Department of Astrophysics, University of Vienna, University of Vienna, Trkenschanzstrasse 17, A-1180 Vienna, Austria

[2] University Observatory Munich, Scheinerstrasse 1, 81679 Munich, Germany

[3] Max-Planck-Fellow, Max-Planck-Institut fr extraterrestrische Physik (MPE), Giessenbachstr. 1, 85748 Garching, Germany

[4] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

E-mail contact: alvaro.hacar *at* univie.ac.at

Context. Since their first detection in the ISM, (sub-)millimeter line observations of different CO isotopic variants have routinely been employed to characterize the kinematic properties of the gas in molecular clouds. Many of these lines exhibit broad linewidths that greatly exceed the thermal broadening expected for the low temperatures found within these objects. These observed suprathermal CO linewidths are assumed to be originated from the presence of unresolved supersonic motions inside clouds.
Aims. The lowest rotational J transitions of some of the most abundant CO isotopologues, ^{12}CO and ^{13}CO, are found to present large optical depths. In addition to well-known line saturation effects, these large opacities present a non-negligible contribution to their observed linewidths. Typically overlooked in the literature, in this paper we aim to quantify the impact of these opacity broadening effects on the current interpretation of the CO suprathermal line profiles.
Methods. Combining large-scale observations and LTE modeling of the ground J=1-0 transitions of the main ^{12}CO, ^{13}CO, C^{18}O isotopologues, we have investigated the correlation of the observed linewidths as a function of the line opacity in different regions of the Taurus molecular cloud.
Results. Without any additional contributions to the gas velocity field, a large fraction of the apparently supersonic ($\mathcal{M} \sim$ 2-3) linewidths measured in both ^{12}CO and ^{13}CO (J=1-0) lines can be explained by the saturation of their corresponding sonic-like, optically-thin C^{18}O counterparts assuming standard isotopic fractionation. Combined with the presence of multiple components detected in some of our C^{18}O spectra, these opacity effects seem to be also responsible of most of the highly supersonic linewidths ($\mathcal{M} >$ 8-10) detected in some of the broadest ^{12}CO and ^{13}CO spectra in Taurus.
Conclusions. Our results demonstrate that most of the suprathermal ^{12}CO and ^{13}CO linewidths reported in nearby clouds like Taurus could be primarily created by a combination of opacity broadening effects and multiple gas velocity components blended in these saturated emission lines. Once corrected by their corresponding optical depth, each of these gas components present transonic intrinsic linewidths consistently traced by the three ^{12}CO, ^{13}CO, and C^{18}O isotopologues with differences within a factor of 2. Highly correlated and velocity-coherent at large scales, the largest and highly supersonic velocity differences inside clouds are generated by the relative motions between individual gas components. In contrast to the classical interpretation within the framework of microscopic turbulence, this highly discretized structure of the molecular gas traced in CO suggest that the gas dynamics inside molecular clouds could be better described by the properties of a fully-resolved macroscopic turbulence.

Accepted by A&A

http://adsabs.harvard.edu/pdf/2016arXiv160308521H

Forming Chondrites in a Solar Nebula with Magnetically Induced Turbulence

Yasuhiro Hasegawa[1], Neal J. Turner[1], Joseph Masiero[1], Shigeru Wakita[2], Yuji Matsumoto[2], Shoichi Oshino[2]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

[2] Center for Computational Astrophysics, National Astronomical Observatory of Japan, Osawa, Mitaka, Tokyo 181-8588, Japan

E-mail contact: yasuhiro *at* caltech.edu

Chondritic meteorites provide valuable opportunities to investigate the origins of the solar system. We explore impact jetting as a mechanism of chondrule formation and subsequent pebble accretion as a mechanism of accreting chondrules onto parent bodies of chondrites, and investigate how these two processes can account for the currently available meteoritic data. We find that when the solar nebula is $\leq$5 times more massive than the minimum-mass solar nebula at $a \approx 2$–3 AU and parent bodies of chondrites are $\leq 10^{24}$ g ($\leq$500 km in radius) in the solar nebula, impact jetting and subsequent pebble accretion can reproduce a number of properties of the meteoritic data. The properties include the present asteroid belt mass, the formation timescale of chondrules, and the magnetic field strength of the nebula derived from chondrules in Semarkona. Since this scenario requires a first generation of planetesimals that trigger impact jetting and serve as parent bodies to accrete chondrules, the upper limit of parent bodies' masses leads to the following implications: primordial asteroids that were originally $\geq 10^{24}$ g in mass were unlikely to contain chondrules, while less massive primordial asteroids likely had a chondrule-rich surface layer. The scenario developed from impact jetting and pebble accretion can therefore provide new insights into the origins of the solar system.

Accepted by ApJL

http://arxiv.org/pdf/1603.00086

A proposed new diagnostic for Herbig disc geometry: FWHM versus J of CO ro-vibrational lines

R.P. Hein Bertelsen[1], I. Kamp[1], G. van der Plas[2], M.E. van den Ancker[3], L.B.F.M. Waters[4,5], W.-F. Thi[6], and P. Woitke[7]

[1] Kapteyn Astronomical Institute Rijks-universiteit Groningen (RuG), Landleven 12, Groningen 9747 Netherlands
[2] Departamento de Astronoma, Universidad de Chile, Casilla 36-D, Santiago, Chile
[3] European Southern Observatory, Karl-Schwarzschild-Str.2, D 85748 Garching bei München, Germany
[4] Anton Pannekoek Astronomical Institute, University of Amsterdam, PO Box 94249, 1090 GE Amsterdam, The Netherlands
[5] SRON Netherlands Institute for Space Research, Sorbonnelaan 2, 3584 CA Utrecht, The Netherlands
[6] UJF-Grenoble 1 / CNRS-INSU, Institut de Plantologie et d'Astrophysique (IPAG) UMR 5274, Grenoble, F-38041, France
[7] SUPA, School of Physics & Astronomy, University of St. Andrews, North Haugh, St. Andrews KY16 9SS, UK

E-mail contact: bertelsen *at* astro.rug.nl

Aims. CO ro-vibrational lines observed from Herbig group II discs are seen to be often broad while the same lines observed from group I discs are often narrow. This difference is not well understood. In this paper we explore the underlying cause for this difference and provide a pathway for a better understanding of the geometry and structure of the inner discs around Herbig Ae/Be stars.
Methods. High-spectral-resolution infrared spectra of CO ro-vibrational emission from six Herbig Ae/Be candidate stars were taken with CRIRES (CRyogenic high-resolution InfraRed Echelle Spectrograph) at the VLT (Very Large Telescope). From these spectra, we produce individual and co-added CO ro-vibrational line profiles. We investigate line profile shape differences, and we explore the FWHM (Full Width Half Maximum) variations with J quantum number in the context of disc geometry. Furthermore, we put our new sources into the context of earlier observed sources to study a large sample. For comparison, we also investigate the FWHM variations with J of modelled CO ro-vibrational lines from two typical disc geometries produced with the thermo-chemical disc modelling code ProDiMo.
Results. Comparing dust and gas inner disc geometries (inferred by SED and CO ro-vibrational emission) for the expanded sample of observed Herbig discs, we find no clear correspondence between the SED groups of the sources and their inner CO radius.
Conclusions. The FWHM versus J is a potential new gas diagnostic for the inner disc with e.g. a constant FWHM versus J indicating the presence of a large gas hole or gap. Both models and observations indicate the potential of this new diagnostic.

Accepted by A&A

http://arxiv.org/pdf/1603.03546

Chemical and physical characterization of collapsing low-mass prestellar dense cores

U. Hincelin[1], B. Commerçon[2], V. Wakelam[3,4], F. Hersant[3,4], S. Guilloteau[3,4], E. Herbst[5]

[1] Department of Chemistry, University of Virginia, Charlottesville, VA 22904, USA
[2] Ecole Normale Supérieure de Lyon, CRAL, UMR 5574 du CNRS, Université Lyon I, 46 Allée d'Italie, 69364 Lyon cedex 07, France
[3] Univ. Bordeaux, LAB, UMR 5804, F-33270, Floirac, France
[4] CNRS, LAB, UMR 5804, F-33270, Floirac, France
[5] Departments of Chemistry and Astronomy, University of Virginia, Charlottesville, VA 22904, USA

E-mail contact: ugo.hincelin *at* gmail.com

The first hydrostatic core, also called the first Larson core, is one of the first steps in low-mass star formation, as predicted by theory. With recent and future high performance telescopes, details of these first phases become accessible, and observations may confirm theory and even bring new challenges for theoreticians. In this context, we study from a theoretical point of view the chemical and physical evolution of the collapse of prestellar cores until the formation of the first Larson core, in order to better characterize this early phase in the star formation process. We couple a state-of-the-art hydrodynamical model with full gas-grain chemistry, using different assumptions on the magnetic field strength and orientation. We extract the different components of each collapsing core (i.e., the central core, the outflow, the disk, the pseudodisk, and the envelope) to highlight their specific physical and chemical characteristics. Each component often presents a specific physical history, as well as a specific chemical evolution. From some species, the components can clearly be differentiated. The different core models can also be chemically differentiated. Our simulation suggests some chemical species as tracers of the different components of a collapsing prestellar dense core, and as tracers of the magnetic field characteristics of the core. From this result, we pinpoint promising key chemical species to be observed.

Accepted by ApJ

http://arxiv.org/pdf/1603.02529

Fundamental stellar parameters for selected T-Tauri stars in the Chamaeleon and ρ Ophiuchus star-forming regions

David James[1], Alicia Aarnio[2], Alexander Richert[3], Phillip Cargile[4], Nuno Santo[5,6], Claudio Melo[7], Jerome Bouvier[8]

[1] Cerro Tololo InterAmerican Observatory, Casilla 603, La Serena, Chile
[2] University of Michigan Department of Astronomy, 403 West Hall, 1085 S. University Ave, Ann Arbor, MI 48109, USA
[3] Department of Astronomy and Astrophysics, The Pennsylvania State University, 525 Davey Lab, University Park, PA 16802, USA
[4] Harvard-Smithsonian Center for Astrophysics, 60 Garden St, Cambridge, MA 02138, USA
[5] Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto, CAUP, Rua das Estrelas, 4150-762 Porto, Portugal
[6] Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, Rua do Campo Alegre, 4169-007 Porto, Portugal
[7]European Southern Observatory (ESO), Casilla 19001, Santiago 19, Chile
[8] Laboratoire d'Astrophysique, Observatoire de Grenoble, BP 53, 38041 Grenoble, France

E-mail contact: djj *at* ctio.noao.edu

We present the results of an optical photometry and high-resolution spectroscopy campaign for a modest sample of X-ray selected stars in the Chamaeleon and ρ Ophiuchus star forming regions. With $R \sim 50000$ optical spectra, we establish kinematic membership of the parent association and confirm stellar youth for each star in our sample. With the acquisition of new standardized $BVIc$ photometry, in concert with near-infrared data from the literature, we derive age and mass from stellar positions in model-dependent Hertzsprung-Russell diagrams. We compare isochronal ages derived using colour-dependent extinction values finding that, within error bars, ages are the same irrespective of whether $E(B-V)$, $E(V-Ic)$, $E(J-H)$ or $E(H-K)$ is used to establish extinction, although model ages tend to be marginally younger for redder $E_{\rm colour}$ values. For Cham I and η Cham members we derive ages of $\lesssim$5–6 Myr, whereas

our three η Cha candidates are more consistent with a $\gtrsim$25 Myr post-T Tauri star population. In ρ Ophiuchus, most stars in our sample have isochronal ages <10 Myr. Five objects show evidence of strong infrared excess ($A_V > 5$) in the 2MASS colour colour diagram, however in terms of Hα emission, all stars except RXJ1625.6−2613 are consistent with being weak-lined T-Tauri stars. Spectral energy distributions (SEDs) over the range ∼4000 Å < wavelength < 1000 μm, show that only one Chamaeleon star (RXJ1112.7−7637) and three ρ Ophiuchus stars (ROXR1 13, RXJ1625.6−2613 & RXJ1627.1−2419) reveal substantial departures from a bare photosphere.

Accepted by MNRAS

http://arxiv.org/pdf/1603.00820

Mass constraint for a planet in a protoplanetary disk from the gap width

Kazuhiro D. Kanagawa[1,2], Takayuki Muto[3], Hidekazu Tanaka[1], Takayuki Tanigawa[4], Taku Takeuchi[5], Takashi Tsukagoshi[6], Munetake Momose[6]

[1] Institute of Low Temperature Science, Hokkaido University, Sapporo 060-0819, Japan
[2] Institute of Physics and CASA, Faculty of Mathematics and Physics, University of Szczecin, Wielkopolska 15, 70-451 Szczecin, Poland
[3] Division of Liberal Arts, Kogakuin University, 1-24-2, Nishi-Shinjuku, Shinjuku-ku, Tokyo, 163-8677, Japan
[4] School of Medicine, University of Occupational and Environmental Health, Yahatanishi-ku, Kitakyushu, Fukuoka 807-8555, Japan
[5] Department of Earth and Planetary Sciences, Tokyo Institute of Technology, Meguro-ku, Tokyo 152-8551, Japan
[6] College of Science, Ibaraki University, 2-1-1, Bunkyo, Mito, Ibaraki 310-851, Japan

E-mail contact: kazuhiro.kanagawa *at* usz.edu.pl

A giant planet creates a gap in a protoplanetary disk, which might explain the observed gaps in protoplanetary disks. The width and depth of the gaps depend on the planet mass and disk properties. We have performed two–dimensional hydrodynamic simulations for various planet masses, disk aspect ratios and viscosities, to obtain an empirical formula for the gap width. The gap width is proportional to the square root of the planet mass, −3/4 power of the disk aspect ratio and −1/4 power of the viscosity. This empirical formula enables us to estimate the mass of a planet embedded in the disk from the width of an observed gap. We have applied the empirical formula for the gap width to the disk around HL Tau, assuming that each gap observed by ALMA observations is produced by planets, and discussed the planet masses within the gaps. The estimate of planet masses from the gap widths is less affected by the observational resolution and dust filtration than that from the gap depth.

Accepted by PASJ

http://arxiv.org/pdf/1603.03853

M Stars in the TW Hya Association: Stellar X-rays and Disk Dissipation

Joel H. Kastner[1], David A. Principe[2,3], Kristina Punzi[1], Beate Stelzer[4], Uma Gorti[5], Ilaria Pascucci[6], Costanza Argiroffi[4,7]

[1] Chester F. Carlson Center for Imaging Science, School of Physics & Astronomy, and Laboratory for Multiwavelength Astrophysics, Rochester Institute of Technology, 54 Lomb Memorial Drive, Rochester NY 14623 USA
[2] Núcleo de Astronomía de la Facultad de Ingeniería, Universidad Diego Portales, Chile
[3] Millennium Nucleus Protoplanetary Disks, Chile
[4] INAF-Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134, Palermo, Italy
[5] SETI Institute, 189 Bernardo Ave., Mountain View, CA 94043, USA; NASA Ames Research Center, Moffett Field, CA 94035, USA
[6] Lunar and Planetary Laboratory, The University of Arizona, Tucson, AZ 85721, USA
[7] Dip. di Fisica e Chimica, Universitá di Palermo, Piazza del Parlamento 1, 90134, Palermo, Italy

E-mail contact: jhk *at* cis.rit.edu

To investigate the potential connection between the intense X-ray emission from young, low-mass stars and the lifetimes of their circumstellar, planet-forming disks, we have compiled the X-ray luminosities (L_X) of M stars in the ∼8 Myr-old TW Hya Association (TWA) for which X-ray data are presently available. Our investigation includes

analysis of archival Chandra data for the TWA binary systems TWA 8, 9, and 13. Although our study suffers from poor statistics for stars later than M3, we find a trend of decreasing L_X/L_{bol} with decreasing T_{eff} for TWA M stars wherein the earliest-type (M0–M2) stars cluster near $\log(L_X/L_{bol}) \approx -3.0$ and then $\log(L_X/L_{bol})$ decreases, and its distribution broadens, for types M4 and later. The fraction of TWA stars that display evidence for residual primordial disk material also sharply increases in this same (mid-M) spectral type regime. This apparent anticorrelation between the relative X-ray luminosities of low-mass TWA stars and the longevities of their circumstellar disks suggests that primordial disks orbiting early-type M stars in the TWA have dispersed rapidly as a consequence of their persistent large X-ray fluxes. Conversely, the disks orbiting the very lowest-mass pre-MS stars and pre-MS brown dwarfs in the Association may have survived because their X-ray luminosities and, hence, disk photoevaporation rates are very low to begin with, and then further decline relatively early in their pre-MS evolution.

Accepted by AJ

http://arxiv.org/pdf/1603.09307

The Nearest Isolated Member of the TW Hydrae Association is a Giant Planet Analog

Kendra Kellogg[1], Stanimir Metchev[1,2], Jonathan Gagné[3,5] and Jacqueline Faherty[3,4,6]

[1] The University of Western Ontario, Centre for Planetary and Space Exploration, Department of Physics & Astronomy, 1151 Richmond St, London, ON N6A 3K7, Canada
[2] Stony Brook University, Department of Physics & Astronomy, 100 Nicolls Rd, Stony Brook, NY 11794-3800, USA
[3] Carnegie Institution of Washington DTM, 5241 Broad Branch Road NW, Washington, DC 20015, USA
[4] Department of Astrophysics, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10034, USA
[5] NASA Sagan Fellow
[6] Hubble Fellow

E-mail contact: kkellogg *at* uwo.ca

In a recent search for unusually red L and T dwarfs, we identified 2MASS J11193254-1137466 as a likely young L7 dwarf and potential member of the TW Hydrae association. We present spectra that confirm the youth of this object. We also measure a radial velocity of $8.5 \pm 3.3\,\mathrm{km\,s^{-1}}$ that, together with the sky position, proper motion and photometric distance, results in a 92% probability of membership in the TW Hydrae association, with a calibrated field contamination probability of 0.0005% using the BANYAN II tool. Using the age of TW Hydrae and the luminosity of 2MASS J11193254-1137466, we estimate its mass to be 4.3–7.6 $M_{\rm Jup}$. It is the lowest-mass and nearest isolated member of TW Hydrae at a kinematic distance of 28.9 ± 3.6 pc, and the second-brightest isolated $<10\,M_{\rm Jup}$ object discovered to date.

Accepted by Astrophysical Journal Letters

http://arxiv.org/pdf/1603.08529

Cold CO gas in the disk of the young eruptive star EX Lup

Á. Kóspál[1,2], P. Ábrahám[1], T. Csengeri[3], U. Gorti[4,5], Th. Henning[2], A. Moór[1], D. A. Semenov[2], L. Szűcs[6], and R. Güsten[3]

[1] Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, P.O. Box 67, 1525 Budapest, Hungary
[2] Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
[3] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
[4] SETI Institute, Mountain View, CA, USA
[5] NASA Ames Research Center, Moffett Field, CA, USA
[6] Max-Planck-Institut für Extraterrestrische Physik, D-85741 Garching, Germany

E-mail contact: kospal *at* konkoly.hu

EX Lupi-type objects (EXors) form a sub-class of T Tauri stars, defined by sudden sporadic flare-ups of 1–5 mag at optical wavelengths. These eruptions are attributed to enhanced mass accretion from the circumstellar disk to the star, and may constitute important events in shaping the structure of the inner disk and the forming planetary system.

Although disk properties must play a fundamental role in driving the outbursts, they are surprisingly poorly known. In order to characterize the dust and gas components of EXor disks, here we report on observations of the ^{12}CO J=3–2 and 4–3 lines, and the ^{13}CO J=3–2 line in EX Lup, the prototype of the EXor class. We reproduce the observed line fluxes and profiles with a line radiative transfer model and compare the obtained parameters with corresponding ones of other T Tauri disks.

Accepted by Astrophysical Journal Letters.

http://arxiv.org/pdf/1603.02855

Gravitational Instabilities in Circumstellar Disks

Kaitlin M. Kratter[1] and Giuseppe Lodato[2]

[1] Department of Astronomy and Steward Observatory, Univ. of Arizona, 933 N Cherry Ave, Tucson, AZ, 85721, USA
[2] Dipartimento di Fisica, Universitá degli Studi di Milan, Via Celoria 16, 20133 Milan, Italy

E-mail contact: kaitlin.kratter *at* gmail.com

Star and planet formation are the complex outcomes of gravitational collapse and angular momentum transport mediated by protostellar and protoplanetary disks. In this review we focus on the role of gravitational instability in this process. We begin with a brief overview of the observational evidence for massive disks that might be subject to gravitational instability, and then highlight the diverse ways in which the instability manifests itself in protostellar and protoplanetary disks: the generation of spiral arms, small scale turbulence-like density fluctuations, and fragmentation of the disk itself. We present the analytic theory that describes the linear growth phase of the instability, supplemented with a survey of numerical simulations that aim to capture the non-linear evolution. We emphasize the role of thermodynamics and large scale infall in controlling the outcome of the instability. Despite apparent controversies in the literature, we show a remarkable level of agreement between analytic predictions and numerical results. We highlight open questions related to (1) the development of a turbulent cascade in thin disks, and (2) the role of mode-mode coupling in setting the maximum angular momentum transport rate in thick disks.

Accepted by ARAA

http://arxiv.org/pdf/1603.01280

Geometry-Independent Determination of Radial Density Distributions in Molecular Cloud Cores and Other Astronomical Objects

Marko Krco[1] and Paul F. Goldsmith[2]

[1] Cornell University, Ithaca, NY 14853 USA
[2] Jet Propulsion Laboratory, Pasadena, CA 91109 and Cornell Unive rsity, Ithaca NY 14853, USA

E-mail contact: marko *at* astro.cornell.edu

We present a geometry-independent method for determining the shapes of radial volume density profiles of astronomical objects whose geometries are unknown, based on a single column density map. Such profiles are often critical to understand the physics and chemistry of molecular cloud cores, in which star formation takes place. The method presented here does not assume any geometry for the object being studied, thus removing a significant source of bias. Instead it exploits contour self-similarity in column density maps which appears to be common in data for astronomical objects. Our method may be applied to many types of astronomical objects and observable quantities so long as they satisfy a limited set of conditions which we describe in detail. We derive the method analytically, test it numerically, and illustrate its utility using 2MASS-derived dust extinction in molecular cloud cores. While not having made an extensive comparison of different density profiles, we find that the overall radial density distribution within molecular cloud cores is adequately described by an attenuated power law.

Accepted by Astrophysical Journal

http://arxiv.org/pdf/1602.07590

Dust diffusion and settling in the presence of collisions: Trapping (sub)micron grains in the midplane

Sebastiaan Krijt[1] and Fred J. Ciesla[1]

[1] Department of the Geophysical Sciences, The University of Chicago, 5734 South Ellis Avenue, Chicago, IL 60637, USA

E-mail contact: skrijt *at* uchicago.edu

In protoplanetary disks, the distribution and abundance of small (sub)micron grains are important for a range of physical and chemical processes. For example, they dominate the optical depth at short wavelengths and their surfaces are the sites of many important chemical reactions such as the formation of water. Based on their aerodynamical properties (i.e., their strong dynamical coupling with the surrounding gas) it is often assumed that these small grains are well-mixed with the gas. Our goal is to study the vertical (re)distribution of grains taking into account settling, turbulent diffusion, as well as collisions with other dust grains. Assuming a fragmentation-limited background dust population, we developed a Monte Carlo approach that follows single monomers as they move through a vertical column of gas and become incorporated in different aggregates as they undergo sticking and fragmenting collisions. We find that (sub)micron grains are not necessarily well-mixed vertically, but can become trapped in a thin layer with a scale-height that is significantly smaller than that of the gas. This collisional trapping occurs when the timescale for diffusion is comparable to or longer than the collision timescale in the midplane and its effect is strongest when the most massive particles in the size-distribution show significant settling. Based on simulations and analytical considerations we conclude that for typical dust-to-gas ratios and turbulence levels, the collisional trapping of small grains should be a relatively common phenomenon. The absence of trapping could then indicate a low dust-to-gas ratio, possibly because a large portion of the dust mass has been removed through radial drift or is locked up in planetesimals.

Accepted by ApJ

http://arxiv.org/pdf/1603.02630

Velocity-resolved hot water emission detected toward HL Tau with the Submillimeter Array

Lars E. Kristensen[1], Joanna M. Brown[1], David Wilner[1] and Colette Salyk[2]

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

[2] Vassar College, Department of Physics and Astronomy, 124 Raymond Avenue, Poughkeepsie, NY 12604, USA

E-mail contact: lars.kristensen *at* nbi.ku.dk

Using the Submillimeter Array (SMA) on Mauna Kea, the $H_2^{16}O$ $10_{2,9}$–$9_{3,6}$ transition ($E_{\rm up}$=1863 K) at 321.2 GHz has been detected toward the embedded low-mass protostar HL Tau. The line centroid is blue-shifted by 15 $\rm km\,s^{-1}$ with respect to the source velocity, and it has a $FWHM$ of 20 $\rm km\,s^{-1}$. The emission is tentatively resolved and extends ∼3–4″ over the sky (∼2 beams), or ∼500 AU at the distance of Taurus. The velocity offset, and to a lesser degree the spatial extent of the emission, shows that the line originates in the protostellar jet or wind. This result suggests that at least some water emission observed toward embedded sources, and perhaps also disk sources, with *Herschel* and *Spitzer* contains a wind or jet component, which is crucial for interpreting these data. These pathfinder observations done with the SMA opens a new window to studying the origin of water emission with e.g. ALMA, thus providing new insights into where water is in protostellar systems.

Accepted by ApJL

http://arxiv.org/pdf/1603.09594

The effects of short-lived radionuclides and porosity on the early thermo-mechanical evolution of planetesimals

Tim Lichtenberg[1,2], Gregor J. Golabek[2,3], Taras V. Gerya[2] and Michael R. Meyer[1]

[1] Institute for Astronomy, ETH Zurich, Wolfgang-Pauli-Strasse 27, 8093 Zurich, Switzerland

[2] Institute of Geophysics, ETH Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland

[3] Bayerisches Geoinstitut, University of Bayreuth, Universitaetsstrasse 30, 95440 Bayreuth, Germany

E-mail contact: tim.lichtenberg *at* phys.ethz.ch

The thermal history and internal structure of chondritic planetesimals, assembled before the giant impact phase of chaotic growth, potentially yield important implications for the final composition and evolution of terrestrial planets. These parameters critically depend on the internal balance of heating versus cooling, which is mostly determined by the presence of short-lived radionuclides (SLRs), such as aluminum-26 and iron-60, as well as the heat conductivity of the material. The heating by SLRs depends on their initial abundances, the formation time of the planetesimal and its size. It has been argued that the cooling history is determined by the porosity of the granular material, which undergoes dramatic changes via compaction processes and tends to decrease with time. In this study we assess the influence of these parameters on the thermo-mechanical evolution of young planetesimals with both 2D and 3D simulations. Using the code family I2ELVIS/I3ELVIS we have run numerous 2D and 3D numerical finite-difference fluid dynamic models with varying planetesimal radius, formation time and initial porosity. Our results indicate that powdery materials lowered the threshold for melting and convection in planetesimals, depending on the amount of SLRs present. A subset of planetesimals retained a powdery surface layer which lowered the thermal conductivity and hindered cooling. The effect of initial porosity was small, however, compared to those of planetesimal size and formation time, which dominated the thermo-mechanical evolution and were the primary factors for the onset of melting and differentiation. We comment on the implications of this work concerning the structure and evolution of these planetesimals, as well as their behavior as possible building blocks of terrestrial planets.

Accepted by Icarus

http://arxiv.org/pdf/1603.05979
http://dx.doi.org/10.1016/j.icarus.2016.03.004

Star-disk interaction in classical T Tauri stars revealed using wavelet analysis

J. López-Santiago[1], I. Crespo-Chacón[2], E. Flaccomio[3], S. Sciortino[3], G. Micela[3], and F. Reale[3,4]

[1] Dpto. de Astrofísica y Cencias de la Atmósfera, Universidad Complutense de Madrid, E-28040 Madrid, Spain
[2] CEDEX, E-28001 Madrid, Spain
[3] INAF-Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, I-90134 Palermo, Italy
[4] Dipartimento di Fisica e Chimica, Università di Palermo, Piazza del Parlamento 1, I-90134 Palermo, Italy

E-mail contact: jalopezs *at* ucm.es

The extension of the corona of classical T Tauri stars (CTTS) is under discussion. The standard model of magnetic configuration of CTTS predicts that coronal magnetic flux tubes connect the stellar atmosphere to the inner region of the disk. However, differential rotation may disrupt these long loops. The results from Hydrodynamic modeling of X-ray flares observed in CTTS confirming the star-disk connection hypothesis are still controversial. Some authors suggest the presence of the accretion disk prevent the stellar corona to extent beyond the co-rotation radius, while others simply are not confident with the methods used to derive loop lengths. We use independent procedures to determine the length of flaring loops in stars of the Orion Nebula Cluster previously analyzed using Hydrodynamic models. Our aim is to disentangle between the two scenarios proposed. We present a different approach to determine the length of flaring loops based on the oscillatory nature of the loops after strong flares. We use wavelet tools to reveal oscillations during several flares. The subsequent analysis of such oscillations is settle on the Physics of coronal seismology. Our results likely confirm the large extension of the corona of CTTS and the hypothesis of star-disk magnetic interaction in at least three CTTS of the Orion Nebula Cluster. Analyzing oscillations in flaring events is a powerful tool to determine the physical characteristics of magnetic loops in coronae in stars other than the Sun. The results presented in this work confirm the star-disk magnetic connection in CTTS.

Accepted by A&A

http://arxiv.org/pdf/1603.06144

The role of SiO as a tracer of past star-formation events: The case of the high-mass protocluster NGC 2264-C

Ana Lopez-Sepulcre[1], Yoshimasa Watanabe[1], Nami Sakai[2], Ryuta Furuya[1], Osamu Saruwatari[1] and Satoshi Yamamoto[1]

[1] Department of Physics, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[2] RIKEN, Chemistry and Materials Physics Building, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan

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

NGC 2264-C is a high-mass protocluster where several star-formation events are known to have occurred. To investigate whether past protostellar activity has left a chemical imprint in this region, we mapped it in SiO($J = 2-1$), a shock tracer, and several other molecular lines with the Nobeyama 45 m telescope. Our observations show the presence of a complex network of protostellar outflows. The strongest SiO emission lies beyond a radius of ~ 0.1 pc with respect to the center of the clump, and is characterized by broad (> 10 km s^{-1}) lines and abundances of $\sim 1.4 \times 10^{-8}$ with respect to H_2. Interestingly, SiO appears relatively depleted ($\chi_{\rm SiO} \sim 4 \times 10^{-9}$) within this radius, despite it being affected by molecular outflow activity. We attribute this to fast condensation of SiO back onto dust grains and/or rapid gas-phase destruction of SiO, favored by the high density present in this area ($> 10^6$ cm^{-3}). Finally, we identify a peripheral, narrow-line (~ 2 km s^{-1}) component, where SiO has an abundance of a few times 10^{-11}. After considering different options, we conclude that this weak emission may be tracing protostellar shocks from the star formation episode that preceded the current one, which have decelerated over time and eventually resulted in SiO being largely depleted/destroyed. Alternatively, a population of unresolved low-mass protostars may be responsible for the narrow SiO emission. High-angular resolution observations are necessary to distinguish between these two possibilities and thus understand the role of SiO as a chemical tracer of past star-formation episodes in massive protoclusters.

Accepted by ApJ

http://arxiv.org/pdf/1603.05885v1.pdf

Young and embedded clusters in Cygnus-X: evidence for building up the initial mass function?

Francisco F. S. Maia[1,2,3], Estelle Moraux[1,2] and Isabelle Joncour[1,2]

[1] Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France
[2] CNRS, IPAG, F-38000 Grenoble, France
[3] CAPES Foundation, Ministry of Education of Brazil, Braslia DF 70040-020, Brazil

E-mail contact: ffsmaia *at* ufmg.br

We provide a new view on the Cygnus-X north complex by accessing for the first time the low mass content of young stellar populations in the region. Canada-France-Hawaii Telescope/Wide-Field Infrared Camera was used to perform a deep near-infrared survey of this complex, sampling stellar masses down to 0.1 M$\odot$. Several analysis tools, including a extinction treatment developed in this work, were employed to identify and uniformly characterize a dozen unstudied young star clusters in the area. Investigation of their mass distributions in low-mass domain revealed a relatively uniform log-normal initial mass function (IMF) with a characteristic mass of 0.32±0.08 M$\odot$ and mass dispersion of 0.40±0.06. In the high-mass regime, their derived slopes showed that while the youngest clusters (age $<$ 4 Myr) presented slightly shallower values with respect to the Salpeter's, our older clusters (4 Myr $<$ age $<$ 18 Myr) showed IMF compliant values and a slightly denser stellar population. Although possibly evidencing a deviation from an 'universal' IMF, these results also supports a scenario where these gas-dominated young clusters gradually 'build up' their IMF by accreting low-mass stars formed in their vicinity during their first ∼3 Myr, before the gas expulsion phase, emerging at the age of ∼4 Myr with a fully fledged IMF. Finally, the derived distances to these clusters confirmed the existence of at least three different star-forming regions throughout Cygnus-X north complex, at distances of 500-900 pc, 1.4-1.7 and 3.0 kpc, and revealed evidence of a possible interaction between some of these stellar populations and the Cygnus OB2 association.

Accepted by MNRAS

http://arxiv.org/pdf/1602.07341

On the Formation of Super-Earths with Implications for the Solar System

Rebecca G. Martin[1] and Mario Livio[1]

[1] Department of Physics and Astronomy, University of Nevada, Las Vegas, 4505 South Maryland Parkway, Las Vegas, NV 89154, USA

E-mail contact: rebecca.martin *at* unlv.edu

We first consider how the level of turbulence in a protoplanetary disk affects the formation locations for the observed close-in super-Earths in exosolar systems. We find that a protoplanetary disk that includes a dead zone (a region of low turbulence) has substantially more material in the inner parts of the disk, possibly allowing for in situ formation. For the dead zone to last the entire lifetime of the disk requires the active layer surface density to be sufficiently small, <100 g cm^{-2}. Migration through a dead zone may be very slow and thus super-Earth formation followed by migration towards the star through the dead zone is less likely. For fully turbulent disks, there is not enough material for in situ formation. However, in this case, super-Earths can form farther out in the disk and migrate inwards on a reasonable timescale. We suggest that both of these formation mechanisms operate in different planetary systems. This can help to explain the observed large range in densities of super-Earths because the formation location determines the composition. Furthermore, we speculate that super-Earths could have formed in the inner parts of our solar system and cleared the material in the region inside of Mercury's orbit. The super-Earths could migrate through the gas disk and fall into the Sun if the disk was sufficiently cool during the final gas disk accretion process. While it is definitely possible to meet all of these requirements, we don't expect them to occur in all systems, which may explain why the solar system is somewhat special in its lack of super-Earths.

Accepted by ApJ

http://arxiv.org/pdf/1603.08145

Photo-reverberation Mapping of a Protoplanetary Accretion Disk around a T Tauri Star

Huan Y. A. Meng[1,2,3], Peter Plavchan[1,4], George H. Rieke[2,3], Ann Marie Cody[5], Tina Güth[6], John Stauffer[7], Kevin Covey[8], Sean Carey[7], David Ciardi[1], Maria C. Duran-Rojas[9], Robert A. Gutermuth[10], María Morales-Calderón[11], Luisa M. Rebull[7], Alan M. Watson[12]

[1] Infrared Processing and Analysis Center, California Institute of Technology, MC 100-22, 770 S Wilson Ave, Pasadena, CA 91125, USA

[2] Lunar and Planetary Laboratory and Department of Planetary Sciences, University of Arizona, 1629 E University Blvd, Tucson, AZ 85721, USA

[3] Steward Observatory and Department of Astronomy, University of Arizona, 933 N Cherry Ave, Tucson, AZ 85721, USA

[4] Department of Physics, Astronomy and Materials Science, Missouri State University, 901 S National Ave, Springfield, MO 65897

[5] NASA Ames Research Center, Moffett Field, CA 94035, USA

[6] Department of Physics, New Mexico Institute of Mining and Technology, 801 Leroy Pl, Socorro, NM 87801, USA

[7] Infrared Science Archive and Spitzer Science Center, Infrared Processing and Analysis Center, California Institute of Technology, MC 314-6, 1200 E California Blvd, Pasadena, CA 91125, USA

[8] Department of Physics and Astronomy, MS-9164, Western Washington University, 516 High St, Bellingham, WA 98225, USA

[9] Instituto de Astronomía, Universidad Nacional Autónoma de México, Apartado Postal 106, 22800, Ensenada, Baja California, México

[10] Department of Astronomy, University of Massachusetts, Amherst, MA 01003

[11] Centro de Astrobiología, Departamento de Astrofísica, INTA-CSIC, PO Box 78, E-28691, ESAC Campus, Villanueva de la Cañada, Madrid, Spain

[12] Instituto de Astronomía, Universidad Nacional Autónoma de México, Apartado Postal 70-264, 04510 México, D. F., México

E-mail contact: hyameng *at* lpl.arizona.edu

Theoretical models and spectroscopic observations of newborn stars suggest that protoplantary disks have an inner "wall" at a distance set by the disk interaction with the star. Around T Tauri stars, the size of this disk hole is expected to be on a 0.1-AU scale that is unresolved by current adaptive optics imaging, though some model-dependent constraints have been obtained by near-infrared interferometry. Here we report the first measurement of the inner disk wall around a solar-mass young stellar object, YLW 16B in the ρ Ophiuchi star-forming region, by detecting the light travel time of the variable radiation from the stellar surface to the disk. Consistent time lags were detected on two

nights, when the time series in H (1.6 μm) and K (2.2 μm) bands were synchronized while the 4.5 μm emission lagged by 74.5±3.2 seconds. Considering the nearly edge-on geometry of the disk, the inner rim should be 0.084 AU from the protostar on average, with an error of order 0.01 AU. This size is likely larger than the range of magnetospheric truncations, and consistent with an optically and geometrically thick disk front at the dust sublimation radius at ∼1500 K. The widths of the cross-correlation functions between the data in different wavebands place possible new constraints on the geometry of the disk.

Accepted by ApJ

http://arxiv.org/pdf/1603.06000

Dynamical ejections of massive stars from young star clusters under diverse initial conditions

Seungkyung Oh[1,2] and Pavel Kroupa[1]

[1] Helmholtz-Institut für Strahlen- und Kernphysik (HISKP), University of Bonn, Nussallee 14-16, 53115 Bonn, Germany

[2] Argelander Institut für Astronomie, University of Bonn, Auf dem Hügel 71, 53121 Bonn, Germany

E-mail contact: skoh *at* astro.uni-bonn.de

We study the effects that initial conditions of star clusters and their massive star population have on dynamical ejections of massive stars from star clusters up to an age of 3 Myr. We use a large set of direct N-body calculations for moderately massive star clusters ($M_{\rm ecl} \approx 10^{3.5}\,M_\odot$). We vary the initial conditions of the calculations, such as the initial half-mass radius of the clusters, initial binary populations for massive stars and initial mass segregation. We find that the initial density is the most influential parameter for the ejection fraction of the massive systems. The clusters with an initial half-mass radius $r_{\rm h}(0)$ of 0.1 (0.3) pc can eject up to 50% (30)% of their O-star systems on average, while initially larger ($r_{\rm h}(0) = 0.8$ pc) clusters, that is, lower density clusters, eject hardly any OB stars (at most ≈4.5%). When the binaries are composed of two stars of similar mass, the ejections are most effective. Most of the models show that the average ejection fraction decreases with decreasing stellar mass. For clusters that are efficient at ejecting O stars, the mass function of the ejected stars is top-heavy compared to the given initial mass function (IMF), while the mass function of stars that remain in the cluster becomes slightly steeper (top-light) than the IMF. The top-light mass functions of stars in 3 Myr old clusters in our N-body models agree well with the mean mass function of young intermediate-mass clusters in M31, as reported previously. This implies that the IMF of the observed young clusters is the canonical IMF. We show that the multiplicity fraction of the ejected massive stars can be as high as ≈60%, that massive high-order multiple systems can be dynamically ejected, and that high-order multiples become common especially in the cluster. We also discuss binary populations of the ejected massive systems. Clusters that are initially not mass-segregated begin ejecting massive stars after a time delay that is caused by mass segregation. When a large kinematic survey of massive field stars becomes available, for instance through *Gaia*, our results may be used to constrain the birth configuration of massive stars in star clusters. The results presented here, however, already show that the birth mass-ratio distribution for O-star primaries must be near uniform for mass ratios $q \geq 0.1$.

Accepted by A&A

http://arxiv.org/pdf/1604.00006

Mass segregation in star clusters is not energy equipartition

Richard J. Parker[1], Simon P. Goodwin[2], Nicholas J. Wright[3], Michael R. Meyer[4] and Sascha P. Quanz[4]

[1] Astrophysics Research Institute, Liverpool John Moores University, 146 Brownlow Hill, Liverpool, L3 5RF, UK

[2] Department of Physics and Astronomy, University of Sheffield, Sheffield, S3 7RH, UK

[3] Astrophysics Group, Keele University, Keele, Staffordshire, ST5 5BG, UK

[4] Institute for Astronomy, ETH Zürich, Wolfgang-Pauli-Strasse 27, 8093, Zürich, Switzerland

E-mail contact: R.J.Parker *at* ljmu.ac.uk

Mass segregation in star clusters is often thought to indicate the onset of energy equipartition, where the most massive stars impart kinetic energy to the lower-mass stars and brown dwarfs/free floating planets. The predicted net result

of this is that the centrally concentrated massive stars should have significantly lower velocities than fast-moving low-mass objects on the periphery of the cluster. We search for energy equipartition in initially spatially and kinematically substructured N-body simulations of star clusters with $N = 1500$ stars, evolved for 100 Myr. In clusters that show significant mass segregation we find no differences in the proper motions or radial velocities as a function of mass. The kinetic energies of all stars decrease as the clusters relax, but the kinetic energies of the most massive stars do not decrease faster than those of lower-mass stars. These results suggest that dynamical mass segregation – which is observed in many star clusters – is not a signature of energy equipartition from two-body relaxation.

Accepted by MNRAS Letters

http://arxiv.org/pdf/1604.00394

An analytical model for the evolution of starless cores I: The constant-mass case

Kate Pattle[1]

[1] Jeremiah Horrocks Institute, University of Central Lancashire, Preston PR1 2HE, United Kingdom

E-mail contact: kpattle *at* uclan.ac.uk

We propose an analytical model for the quasistatic evolution of starless cores confined by a constant external pressure, assuming that cores are isothermal and obey a spherically-symmetric density distribution. We model core evolution for Plummer-like and Gaussian density distributions in the adiabatic and isothermal limits, assuming Larson-like dissipation of turbulence. We model the variation in the terms in the virial equation as a function of core characteristic radius, and determine whether cores are evolving toward virial equilibrium or gravitational collapse. We ignore accretion onto cores in the current study. We discuss the different behaviours predicted by the isothermal and adiabatic cases, and by our choice of index for the size-linewidth relation, and suggest a means of parameterising the magnetic energy term in the virial equation. We model the evolution of the set of cores observed by Pattle et al. (2015) in the L1688 region of Ophiuchus in the 'virial plane'. We find that not all virially-bound and pressure-confined cores will evolve to become gravitationally bound, with many instead contracting to virial equilibrium with their surroundings, and find an absence of gravitationally-dominated and virially-unbound cores. We hypothesise a 'starless core desert' in this quadrant of the virial plane, which may result from cores initially forming as pressure-confined objects. We conclude that a virially-bound and pressure-confined core will not necessarily evolve to become gravitationally bound, and thus cannot be considered prestellar. A core can only be definitively considered prestellar (collapsing to form an individual stellar system) if it is gravitationally unstable.

Accepted by MNRAS

http://arxiv.org/pdf/1603.09591

The initial conditions for stellar protocluster formation. III. The *Herschel* counterparts of the *Spitzer* Dark Cloud catalogue

N. Peretto[1], C. Lenfestey[2], G. A. Fuller[2], A. Traficante[2], S. Molinari[3], M. A. Thompson[4], D. Ward-Thompson[5]

[1] School of Physics & Astronomy, Cardiff University, Queen's building, The parade, Cardiff, CF24 3AA, UK
[2] Jodrell Bank Centre for Astrophysics, Alan Turing building, School of Physics & Astronomy, The University of Manchester, Oxford Road, Manchester M13 9PL, UK
[3] IAPS-Istituto di Astrofisica e Planetologia Spaziali, Via Fosso del Cavaliere 100, I-00133 Roma, Italy
[4] Centre for Astrophysics Research, University of Hertfordshire, College Lane, Hatfield, Herts AL10 9AB, UK
[5] Jeremiah Horrocks Institute, University of Central Lancashire, Preston, Lancashire PR1 2HE, UK

E-mail contact: nicolas.peretto@astro.cf.ac.uk

Galactic plane surveys of pristine molecular clouds are key for establishing a Galactic-scale view of star formation. For this reason, an unbiased sample of infrared dark clouds in the $10° < |l| < 65°, |b| < 1°$ region of the Galactic plane was built using *Spitzer* 8μm extinction. However, intrinsic fluctuations in the mid-infrared background can be misinterpreted as foreground clouds. The main goal of this study is to disentangle real clouds in the *Spitzer* Dark Cloud (SDC) catalogue from artefacts due to fluctuations in the mid-infrared background. We constructed H_2 column density maps at $\sim 18''$ resolution using the 160μm and 250μm data from the *Herschel* Galactic plane survey Hi-

GAL. We also developed an automated detection scheme that confirms the existence of a SDC through its association with a peak on these *Herschel* column density maps. Detection simulations, along with visual inspection of a small sub-sample of SDCs, have been performed to get more insight into the limitations of our automated identification scheme. Our analysis shows that 76(±19)% of the catalogued SDCs are real. This fraction drops to 55(±12)% for clouds with angular diameters larger than ∼ 1 arcmin. The contamination of the PF09 catalogue by large spurious sources reflects the large uncertainties associated to the construction of the 8μm background emission, a key stage in identifying SDCs. A comparison of the *Herschel* confirmed SDC sample with the BGPS and ATLASGAL samples shows that SDCs probe a unique range of cloud properties, reaching down to more compact and lower column density clouds than any of these two (sub-)millimetre Galactic plane surveys. Even though about half of the large SDCs are spurious sources, the vast majority of the catalogued SDCs do have a *Herschel* counterpart. The *Herschel*-confirmed sample of SDCs offers a unique opportunity to study the earliest stages of both low- and high-mass star formation across the Galaxy.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/1602.03234

Constraining the physical structure of the inner few 100 AU scales of deeply-embedded low-mass protostars

M. V. Persson[1], D. Harsono[1,2], J. J. Tobin[1], E. F. van Dishoeck[1,3], J. K. Jørgensen[4,5], N. Murillo[3] and S.-P. Lai[6,7]

[1] Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA Leiden, The Netherlands
[2] Universität Heidelberg, Zentrum für Astronomie, Institut für Theoretische Astrophysik (ITA), Albert-Ueberle-Str. 2, 69120, Heidelberg, Germany
[3] Max-Planck Institute für extraterrestrische Physik (MPE), Giessenbachstrasse, 85748 Garching, Germany
[4] Centre for Star and Planet Formation, Natural History Museum of Denmark, University of Copenhagen, Øster Voldgade 5-7, 1350, København K, Denmark
[5] Niels Bohr Institute, University of Copenhagen, Juliane Maries Vej 30, 2100 København , Denmark
[6] Institute of Astronomy and Department of Physics, National Tsing Hua University, 101 Section 2 Kuang Fu Road, 30013 Hsinchu, Taiwan
[7] Academia Sinica Institute of Astronomy and Astrophysics, PO Box 23-141, 10617 Taipei, Taiwan

E-mail contact: magnusp *at* strw.leidenuniv.nl

(Abridged) The physical structure of deeply-embedded low-mass protostars (Class 0) on scales of less than 300 AU is still poorly constrained. Determining this is crucial for understanding the physical and chemical evolution from cores to disks. In this study two models of the emission, a Gaussian disk intensity distribution and a parametrized power-law disk model, are fitted to sub-arcsecond resolution interferometric continuum observations of five Class 0 sources, including one source with a confirmed Keplerian disk. For reference, a spherically symmetric single power-law envelope is fitted to the larger scale (∼1000 AU) emission and investigated further for one of the sources on smaller scales. A thin disk model can approximate the emission and physical structure in the inner few 100 AU scales of the studied deeply-embedded low-mass protostars and paves the way for analysis of a larger sample with ALMA. While the disk radii agree with previous estimates the masses are different for some of the sources studied. Assuming a typical temperature distribution, the fractional amount of mass in the disk above 100 K varies in between 7% to 30%. Kinematic data are needed to determine the presence of any Keplerian disk. Using previous observations of p-$H_2{}^{18}O$, we estimate the relative gas phase water abundances roughly an order of magnitude higher than previously inferred when both warm and cold H_2 was used as reference. A spherically symmetric single power-law envelope model fails to simultaneously reproduce both the small and large scale emission.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/1603.01061

Highly Excited H_2 in Herbig-Haro 7: Formation Pumping in Shocked Molecular Gas?

R.E. Pike[1], T.R. Geballe[2], M.G. Burton[3,4], A. Chrysostomou[5]

[1] Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada
[2] Gemini Observatory, Hilo, HI, USA

[3] School of Physics, University of New South Wales, Sydney, Australia
[4] Armagh Observatory and Planetarium, College Hill, Armagh BT61 9DG, Northern Ireland, UK
[5] Centre for Astrophysics Research, University of Hertfordshire, UK

E-mail contact: repike *at* uvic.ca

We have obtained K-band spectra at $R \sim 5{,}000$ and angular resolution $0\farcs3$ of a section of the Herbig-Haro 7 (HH7) bow shock, using the Near-Infrared Integral Field Spectrograph at Gemini North. Present in the portion of the data cube corresponding to the brightest part of the bow shock are emission lines of H_2 with upper state energies ranging from ∼6,000 K up to the dissociation energy of H_2, ∼50,000 K. Because of low signal-to-noise ratios, the highest excitation lines cannot be easily seen elsewhere in the observed region. However, excitation temperatures, measured throughout much of the observed region using lines from levels as high as 25,000 K, are a strong function of upper level energy, indicating that the very highest levels are populated throughout. The level populations in the brightest region are well fit by a two-temperature model, with 98.5% of the emitting gas at $T = 1800$ K and 1.5% at $T = 5200$ K. The bulk of the H_2 line emission in HH7, from the 1,800 K gas, has previously been well modeled by a continuous shock, but the 5,200 K component is inconsistent with standalone standard continuous shock models. We discuss various possible origins for the hot component and suggest that this component is H_2 newly reformed on dust grains and then ejected from them, presumably following dissociation of some of the H_2 by the shock.

Accepted by ApJ

http://arxiv.org/pdf/1603.07145

A star forming ring around κ Ori 250 pc from the Sun

I. Pillitteri[1,2], S.J. Wolk[1], and S.T. Megeath[3]

[1] Harvard-Smithsonian Center for Astrophysics, Cambridge MA 02138, USA
[2] INAF-Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134, Palermo, Italy
[3] Ritter Astrophysical Research Center, Dept. of Physics and Astronomy, University of Toledo, OH ? USA

E-mail contact: ipillitt *at* cfa.harvard.edu

X-rays are a powerful probe of activity in early stages of star formation. They allow us to identify young stars even after they have lost the IR signatures of circumstellar disks and provide constraints on their distance. Here we report on XMM-Newton observations which detect 121 young stellar objects (YSOs) in two fields between L1641S and κ Ori. These observations extend the Survey of Orion A with XMM and Spitzer (SOXS). The YSOs are contained in a ring of gas and dust apparent at millimeter wavelengths, and in far-IR and near-IR surveys. The X-ray luminosity function of the young stellar objects detected in the two fields indicates a distance of 250–280 pc, much closer than the Orion A cloud and similar to distance estimates of κ Ori. We propose that the ring is a 5–8 pc diameter shell that has been swept up by κ Ori. This ring contains several groups of stars detected by Spitzer and WISE including one surrounding the Herbig Ae/Be stars V1818 Ori. In this interpretation, the κ Ori ring is one of several shells swept up by massive stars within the Orion Eridanus Superbubble, and is unrelated to the southern portion of Orion A / L1641 S.

Accepted by ApJL

http://arxiv.org/pdf/1603.00205

WISEA J114724.10−204021.3: A Free-Floating Planetary Mass Member of the TW Hya Association

Adam C. Schneider[1,4], James Windsor[1], Michael C. Cushing[1], J. Davy Kirkpatrick[2], and Edward L. Wright[3]

[1] Department of Physics and Astronomy, University of Toledo, 2801 W. Bancroft St., Toledo, OH 43606, USA
[2] Infrared Processing and Analysis Center, MS 100-22, California Institute of Technology, Pasadena, CA 91125, USA
[3] Department of Physics and Astronomy, UCLA, 430 Portola Plaza, Box 951547, Los Angeles, CA 90095-1547, USA
[4] Visiting Astronomer at the Infrared Telescope Facility, which is operated by the University of Hawaii under contract NNH14CK55B with the National Aeronautics and Space Administration.

E-mail contact: Adam.Schneider *at* Utoledo.edu

We present WISEA J114724.10−204021.3, a young, low-mass, high probability member of the TW Hya association. WISEA J114724.10−204021.3 was discovered based on its red AllWISE color (W1−W2 = 0.63 mag) and extremely red 2MASS $J-K_S$ color (>2.64 mag), the latter of which is confirmed with near-infrared photometry from the VISTA Hemisphere Survey ($J-K_S = 2.57 \pm 0.03$). Follow-up near-infrared spectroscopy shows a spectral type of L7±1 as well as several spectroscopic indicators of youth. These include a peaked H-band shape and a steeper K-band slope, traits typically attributed to low surface gravity. The sky position, proper motion, and distance estimates of WISEA J114724.10−204021.3 are all consistent with membership in the ∼10 Myr old TW Hya association. Using the age of the TW Hya association and evolutionary models, we estimate the mass of WISEA J114724.10−204021.3 to be 5–13 M_{Jup}, making it one of the youngest and lowest mass free-floating objects yet discovered in the Solar neighborhood.

Accepted by ApJL

http://arxiv.org/pdf/1603.07985

Star formation in Galactic flows

Romas Smilgys[1] and Ian A. Bonnell[1]

[1] Scottish Universities Physics Alliance (SUPA), School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews, Fife KY16 9SS, UK

E-mail contact: rs202 *at* st-andrews.ac.uk

We investigate the triggering of star formation in clouds that form in Galactic scale flows as the ISM passes through spiral shocks. We use the Lagrangian nature of SPH simulations to trace how the star forming gas is gathered into self-gravitating cores that collapse to form stars. Large scale flows that arise due to Galactic dynamics create shocks of order 30 km s^{-1} that compress the gas and form dense clouds ($n >$several $\times 10^2$ cm^{-3}) in which self-gravity becomes relevant. These large-scale flows are necessary for creating the dense physical conditions for gravitational collapse and star formation. Local gravitational collapse requires densities in excess of $n > 10^3$ cm^{-3} which occur on size scales of ≈ 1 pc for low-mass star forming regions ($M < 100 M_\odot$), and up to sizes approaching 10 pc for higher-mass regions ($M > 10^3 M_\odot$). Star formation in the 250 pc region lasts throughout the 5 Myr timescale of the simulation with a star formation rate of $\approx 10^{-1} M_\odot$ yr^{-1} kpc^{-2}. In the absence of feedback, The efficiency of the star formation per free-fall time varies from our assumed 100 % at our sink accretion radius to values of $< 10^{-3}$ at low densities.

Accepted by MNRAS

Slingshot Mechanism in Orion: Kinematic Evidence For Ejection of Protostars by Filaments

Amelia M. Stutz[1] and Andrew Gould[1,2]

[1] Max-Planck-Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany
[2] Dept. of Astronomy, Ohio State University, 140 W. 18th Ave., Columbus, OH, USA

E-mail contact: stutz *at* mpia.de

By comparing three constituents of Orion A (gas, protostars, and pre-main-sequence stars), both morphologically and kinematically, we derive the following conclusions. The gas surface density near the integral-shaped filament (ISF) is very well represented by a power law, $\Sigma(b) = 37\,M_\odot\,pc^{-2}(b/pc)^{-5/8}$ for the entire range to which we are sensitive, $0.05\,pc < b < 8.5\,pc$, of projected separation from the filament ridge. Essentially all Class 0 and Class I protostars lie superposed on the ISF or on identifiable filament ridges further south, while almost all pre-main-sequence (Class II) stars do not. Combined with the fact that protostars are moving $\lesssim 1\,\mathrm{km\,s^{-1}}$ relative to the filaments while stars are moving several times faster, this implies that protostellar accretion is terminated by a slingshot-like "ejection" from the filaments. The ISF is the third in a series of identifiable "star bursts" that are progressively moving south, with separations of several Myr in time and 2–3 pc in space. This, combined with the observed undulations in the filament (both spatial and velocity), suggest that repeated propagation of transverse waves through the filament is progressively digesting the material that formerly connected Orion A and B into stars in discrete episodes. We construct a simple, circularly symmetric gas density profile $\rho(r) = 17\,M_\odot\,pc^{-3}(r/pc)^{-13/8}$ consistent with the two-dimensional data. The model implies that the observed magnetic fields in this region are subcritical on spatial scales of the observed undulations, suggesting that the transverse waves propagating through the filament are magnetically

induced. Because the magnetic fields are supercritical on scales of the filament as a whole (as traced by the power law), the system as a whole is relatively stable and long lived. Protostellar "ejection" (i.e., the "slingshot") occurs because the gas accelerates away from the protostars, not the other way around. The model also implies that the ISF is kinematically young, which is consistent with several other lines of evidence. In contrast to the ISF, the southern filament (L1641) has a broken power law, which matches the ISF profile for $2.5\,pc < b < 8.5\,pc$, but is shallower closer in. L1641 is kinematically older than the ISF.

Accepted by A & A

The Bolocam Galactic Plane Survey. XIV. Physical Properties of Massive Starless and Star Forming Clumps

Brian E. Svoboda[1], Yancy L. Shirley[1,2], Cara Battersby[3], Erik W. Rosolowsky[4], Adam G. Ginsburg[5,6], Timothy P. Ellsworth-Bowers[6], Michele R. Pestalozzi[7], Miranda K. Dunham[8], Neal J. Evans II[9], John Bally[6] and Jason Glenn[6]

[1] Steward Observatory, University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721, USA
[2] Adjunct Astronomer, National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, USA
[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[4] Department of Physics, 4-181 CCIS, University of Alberta, Edmonton AB T6G 2E1, Canada
[5] European Southern Observatory, Karl-Schwarzschild Strasse 2, D-85748 Garching bei Munchen, Germany
[6] CASA, University of Colorado, 389-UCB, Boulder, CO 80309, USA
[7] University of Gothenburg, SE-412 96 Gothenburg, Sweden
[8] Department of Astronomy, Yale University, P.O. Box 208101, New Haven, CT 06520, USA
[9] Department of Astronomy, The University of Texas at Austin, 2515 Speedway, Stop C1400, Austin, TX 78712, USA

E-mail contact: svobodb *at* email.arizona.edu

We sort 4683 molecular clouds between $10^\circ < \ell < 65^\circ$ from the Bolocam Galactic Plane Survey based on observational diagnostics of star formation activity: compact 70 μm sources, mid-IR color-selected YSOs, H_2O and CH_3OH masers, and UCHII regions. We also present a combined NH_3-derived gas kinetic temperature and H_2O maser catalog for 1788 clumps from our own GBT 100m observations and from the literature. We identify a subsample of 2223 (47.5%) starless clump candidates, the largest and most robust sample identified from a blind survey to date. Distributions of flux density, flux concentration, solid angle, kinetic temperature, column density, radius, and mass show strong (> 1 dex) progressions when sorted by star formation indicator. The median starless clump candidate is marginally sub-virial ($\alpha \sim 0.7$) with $> 75\%$ of clumps with known distance being gravitationally bound ($\alpha < 2$). These samples show a statistically significant increase in the median clump mass of $\Delta M \sim 170-370$ M$_\odot$ from the starless candidates to clumps associated with protostars. This trend could be due to (i) mass growth of the clumps at $\dot{M} \sim 200-440$ M$_\odot$ Myr^{-1} for an average free-fall 0.8 Myr time-scale, (ii) a systematic factor of two increase in dust opacity from starless to protostellar phases, (iii) and/or a variation in the ratio of starless to protostellar clump lifetime that scales as $\sim M^{-0.4}$. By comparing to the observed number of CH_3OH maser containing clumps we estimate the phase-lifetime of massive ($M > 10^3$ M$_\odot$) starless clumps to be 0.37 ± 0.08 Myr $(M/10^3\ \mathrm{M}_\odot)^{-1}$; the majority ($M < 450$ M$_\odot$) have phase-lifetimes longer than their average free-fall time.

Accepted by ApJ

http://arxiv.org/pdf/1511.08810

Discovery of periodic and alternating flares of the methanol and water masers in G107.298+5.639

M. Szymczak[1], M. Olech[1], P. Wolak[1], A. Bartkiewicz[1] and M. Gawronski[1]

[1] Centre for Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Grudziadzka 5, 87-100 Torun, Poland

E-mail contact: msz *at* astro.umk.pl

Methanol and water vapour masers are signposts of early stages of high-mass star formation but it is generally thought that due to different excitation processes they probe distinct parts of stellar environments. Here we present

observations of the intermediate-mass young stellar object G107.298+5.639, revealing for the first time that 34.4 d flares of the 6.7 GHz methanol maser emission alternate with flares of individual features of the 22 GHz water maser. High angular resolution data reveal that a few components of both maser species showing periodic behaviour coincide in position and velocity and all the periodic water maser components appear in the methanol maser region of size of 360 au. The maser flares could be caused by variations in the infrared radiation field induced by cyclic accretion instabilities in a circumstellar or protobinary disc. The observations do not support either the stellar pulsations or the seed photon flux variations as the underlying mechanisms of the periodicity in the source.

Accepted by MNRAS Letters

http://arxiv.org/pdf/1604.00796

A revised condition for self-gravitational fragmentation of protoplanetary disks

S.Z. Takahashi[1,2,3], Y. Tsukamoto[4], and S. Inutsuka[3]

[1] Astronomical Institute, Tohoku University, 6-3 Aoba, Aramaki-aza, Aoba-ku, Sendai, Miyagi, Japan
[2] Department of Physics, Kyoto University, Oiwake-cho, Kitashirakawa, Sakyo-ku, Kyoto, Japan
[3] Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi, Japan
[4] RIKEN, Wako, Saitama, Japan

E-mail contact: sanemichi *at* astr.tohoku.ac.jp

Fragmentation of protoplanetary disks due to gravitational instabilities is a candidate of a formation mechanism of binary stars, brown dwarfs, and gaseous giant planets. The condition for the fragmentation has been thought that the disk cooling timescale is comparable to its dynamical timescale. However, some numerical simulations suggest that the fragmentation does not occur even if the cooling time is small enough, or the fragmentation can occur even when the cooling is inefficient. To reveal a realistic condition for fragmentation of self-gravitating disks, we perform two-dimensional numerical simulations that take into account the effect of the irradiation of the central star and radiation cooling of the disk, and precisely investigate the structure of the spiral arms formed in the protoplanetary disks. We show that the Toomre Q parameter in the spiral arms is an essential parameter for fragmentation. The spiral arms fragment only when $Q < 0.6$ in the spiral arms. We have further confirmed that this fragmentation condition observed in the numerical simulations can be obtained from the linear stability analysis for the self-gravitating spiral arms. These results indicate that the process of fragmentation of protoplanetary disks is divided into two stages: formation of the spiral arms in the disks; and fragmentation of the spiral arm. Our work reduces the condition for the fragmentation of the protoplanetary disks to the condition of the formation of the spiral arm that satisfies $Q < 0.6$.

Accepted by MNRAS

http://arxiv.org/pdf/1603.01402

The Water Abundance of the Directly Imaged Substellar Companion κ And b Retrieved from a Near Infrared Spectrum

Kamen O. Todorov[1], Michael R. Line[2], Jaime E. Pineda[1,3], Michael R. Meyer[1], Sascha P. Quanz[1], Sasha Hinkley[4] and Jonathan J. Fortney[2]

[1] Institute for Astronomy, ETH Zrich, Wolfgang-Pauli-Strasse 27, 8093, Zrich, Switzerland
[2] Department of Astronomy & Astrophysics, University of California, Santa Cruz, Santa Cruz, CA 95064, USA
[3] Current address: Max Planck Institute for Extraterrestrial Physics, 85748 Garching, Germany
[4] School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK

E-mail contact: todorovk *at* phys.ethz.ch

Spectral retrieval has proven to be a powerful tool for constraining the physical properties and atmospheric compositions of extrasolar planet atmospheres from observed spectra, primarily for transiting objects but also for directly imaged planets and brown dwarfs. Despite its strengths, this approach has been applied to only about a dozen targets. Determining the abundances of the main carbon and oxygen-bearing compounds in a planetary atmosphere can lead to the C/O ratio of the object, which is crucial in understanding its formation and migration history. We present a retrieval analysis on the published near-infrared spectrum of κ And b, a directly imaged substellar companion to a young B9 star. We fit the emission spectrum model utilizing a Markov Chain Monte Carlo algorithm. We estimate

the abundance of water vapor, and its uncertainty, in the atmosphere of the object. In addition, we place an upper limit on the abundance of CH_4. We compare qualitatively our results to studies that have applied model retrieval on multiband photometry and emission spectroscopy of hot Jupiters (extrasolar giant planets with orbital periods of several days) and the directly imaged giant planet HR 8799b.

Accepted by Astrophysical Journal

http://arxiv.org/pdf/1504.00217

Chemistry as a diagnostic of prestellar core geometry

Aris Tritsis[1], Konstantinos Tassis[1,2] and Karen Willacy[3]

[1] Department of Physics, University of Crete, 71003 Heraklion, Greece
[2] IESL, Foundation for Research and Technology-Hellas, 71110 Heraklion, Crete, Greece
[3] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

E-mail contact: tritsis *at* physics.uoc.gr

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

Accepted by Monthly Notices of the Royal Astronomical Society

http://arxiv.org/pdf/1602.03187.pdf

Ejection of gaseous clumps from gravitationally unstable protostellar disks

Eduard Vorobyov[1]

[1] Department of Astrophysics, University of Vienna, Vienna 1180, Austria

E-mail contact: eduard.vorobiev *at* univie.ac.at

We investigate the dynamics of gaseous clumps formed via gravitational fragmentation in young protostellar disks, focusing on the fragments that are ejected from the disk via many-body gravitational interaction. Numerical hydrodynamics simulations were employed to study the evolution of young protostellar disks formed from the collapse of rotating pre-stellar cores with mass in the 1.1-1.6 $M_\odot$ range. Protostellar disks formed in our models undergo gravitational fragmentation driven by continuing mass loading from parental collapsing cores. A few fragments can be ejected from the disk during the early evolution, but the low-mass fragments ($< 15\ M_{\rm Jup}$) disperse creating spectacular bow-type structures while passing through the disk and collapsing core. The least massive fragment that survived the ejection ($21\ M_{\rm Jup}$) straddles the planetary-mass limit, while the most massive ejected fragments ($145\ M_{\rm Jup}$) can break up into several pieces, leading to the ejection of wide separation binary clumps in the brown-dwarf mass range. About half of the ejected fragments are gravitationally bound, the majority is supported by rotation against gravity, and all fragments have the specific angular momentum that is much higher than that expected for brown dwarfs. We found that the internal structure of the ejected fragments is distinct from what would be expected for gravitationally contracting clumps formed via cloud core fragmentation, which can help to differentiate their origin. The ejection of fragments is an important process inherent to massive protostellar disks, which produces freely-floating pre-brown dwarf cores, regulates the disk and stellar masses, and potentially enriches the intracluster medium with processed dust and complex organics.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/1603.07761

SiO: Not the perfect outflow tracer: Outflow studies of the massive star formation region IRAS 19410+2336

F. Widmann[1], H. Beuther[1], P. Schilke[2], and T. Stanke[3]

[1] Max Planck Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany

[2] I. Physikalisches Institut, University of Cologne, Zülpicher Strasse 77, 50937 Köln, Germany

[3] European Southern Observatory, Karl-Schwarzschild-Straße 2, 85748 Garching bei München, Germany

E-mail contact: f.widmann *at* stud.uni-heidelberg.de

Aims. Previous observations of the young massive star formation region IRAS 19410+2336 have revealed strong outflow activity with several interacting outflows. We aim to get a better understanding of the outflow activity in this region by observing the SiO and $H^{13}CO^+$ emission with high angular resolution. SiO is known to trace shocked gas, which is often associated with young energetic outflows. With the $H^{13}CO^+$ data, we intend to better understand the distribution of the quiescent gaseous component of the region.
Methods. The SiO observations in the J=2–1 v=0 transition and $H^{13}CO^+$ J=1–0 observations were performed by the Plateau de Bure Interferometer, combined with IRAM 30 m single-dish observations, in order to get the missing short-spacing information. We complement this new high-resolution observation with earlier CO and H_2 data.
Results. The SiO observations do not trace the previously in CO and H_2 identified outflows well. Although we identify regions of highly increased SiO abundance indicative of shock interaction, there are hardly any bipolar structures in the data. The southern part of the region, which exhibits strong H_2 emission, shows almost no SiO. The CO and SiO data show only weak similarities, and the main SiO emission lies between the two dominating dust clumps of the region.
Conclusions. Most SiO emission is likely to be a result of high-velocity shocks due to protostellar jets. However, this does not explain all the emission features and additional effects; for example, colliding gas flows at the interface of the two main regions may play an important role in the origin of the emission. The present SiO data show that several different effects can influence SiO emission, which makes the interpretation of SiO data more difficult than often assumed.

Accepted by A&A

http://arxiv.org/pdf/1603.01610

Integration of Particle-Gas Systems with Stiff Mutual Drag Interaction

Chao-Chin Yang[1] and Anders Johansen[1]

[1] Lund Observatory, Department of Astronomy and Theoretical Physics, Lund University, Box 43, SE-22100 Lund, Sweden

E-mail contact: ccyang *at* astro.lu.se

Numerical simulation of numerous mm/cm-sized particles embedded in a gaseous disk has become an important tool in the study of planet formation and in understanding the dust distribution in observed protoplanetary disks. However, the mutual drag force between the gas and the particles can become so stiff, particularly because of small particles and/or strong local solid concentration, that an explicit integration of this system is computationally formidable. In this work, we consider the integration of the mutual drag force in a system of Eulerian gas and Lagrangian solid particles. Despite the entanglement between the gas and the particles under the particle-mesh construct, we are able to devise a numerical algorithm that effectively decomposes the globally coupled system of equations for the mutual drag force and makes it possible to integrate this system on a cell-by-cell basis, which considerably reduces the computational task required. We use an analytical solution for the temporal evolution of each cell to relieve the time-step constraint posed by the mutual drag force as well as to achieve the highest degree of accuracy. To validate our algorithm, we use an extensive suite of benchmarks with known solutions in one, two, and three dimensions, including the linear growth and the nonlinear saturation of the streaming instability. We demonstrate numerical convergence and satisfactory consistency in all cases. Our algorithm can for example be applied to model the evolution of the

streaming instability with mm/cm-sized pebbles at high mass loading, which has important consequences for the formation scenarios of planetesimals.

Accepted by The Astrophysical Journal Supplement Series

http://arxiv.org/pdf/1603.08523

Gas Gaps in the Protoplanetary Disk around the Young Protostar HL Tau

Hsi-Wei Yen[1], Hauyu Baobab Liu[2], Pin-Gao Gu[1], Naomi Hirano[1], Chin-Fei Lee[1], Evaria Puspitaningrum[3] and Shigehisa Takakuwa[1,4]

[1] Academia Sinica Institute of Astronomy and Astrophysics, P.O. Box 23-141, Taipei 10617, Taiwan

[2] European Southern Observatory (ESO), Karl-Schwarzschild-Str. 2, D-85748 Garching, Germany

[3] Department of Astronomy, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Jl. Ganesha 10, Bandung 40132 Indonesia

[4] Department of Physics and Astronomy, Graduate School of Science and Engineering, Kagoshima University, 1-21-35 Korimoto, Kagoshima, Kagoshima 890-0065, Japan

E-mail contact: hwyen *at* asiaa.sinica.edu.tw

We have analyzed the HCO^+ (1–0) data of the Class I–II protostar, HL Tau, obtained from the Atacama Large Millimeter/Submillimeter Array long baseline campaign. We generated the HCO^+ image cube at an angular resolution of ∼0.07" (∼10 AU), and performed azimuthal averaging on the image cube to enhance the signal-to-noise ratio and measure the radial profile of the HCO^+ integrated intensity. Two gaps at radii of ∼28 AU and ∼69 AU and a central cavity are identified in the radial intensity profile. The inner HCO^+ gap is coincident with the millimeter continuum gap at a radius of 32 AU. The outer HCO^+ gap is located at the millimeter continuum bright ring at a radius of 69 AU and overlaps with the two millimeter continuum gaps at radii of 64 AU and 74 AU. On the contrary, the presence of the central cavity is likely due to the high optical depth of the 3 mm continuum emission and not the depletion of the HCO^+ gas. We derived the HCO^+ column density profile from its intensity profile. From the column density profile, the full-width-half-maximum widths of the inner and outer HCO^+ gaps are both estimated to be ∼14 AU, and their depths are estimated to be ∼2.4 and ∼5.0. These results are consistent with the expectation from the gaps opened by forming (sub-)Jovian mass planets, while placing tight constraints on the theoretical models solely incorporating the variation of dust properties and grain sizes.

Accepted by ApJL

http://arxiv.org/pdf/1603.01378

Probing Planet Forming Zones with Rare CO Isotopologues

Mo Yu[1], Karen Willacy[2], Sarah E. Dodson-Robinson[3], Neal J. Turner[2] and Neal J. Evans II[1]

[1] Astronomy Department, University of Texas, 1 University Station C1400, Austin, TX 78712, USA

[2] Mail Stop 169-506, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA

[3] University of Delaware, Department of Physics and Astronomy, 217 Sharp Lab, Newark, DE 19716, USA

E-mail contact: moyu *at* astro.as.utexas.edu

The gas near the midplanes of planet-forming protostellar disks remains largely unprobed by observations due to the high optical depth of commonly observed molecules such as CO and H_2O. However, rotational emission lines from rare molecules may have optical depths near unity in the vertical direction, so that the lines are strong enough to be detected, yet remain transparent enough to trace the disk midplane. Here we present a chemical model of an evolving T-Tauri disk and predict the optical depths of rotational transitions of $^{12}C^{16}O$, $^{13}C^{16}O$, $^{12}C^{17}O$ and $^{12}C^{18}O$. The MRI-active disk is primarily heated by the central star due to the formation of the dead zone. CO does not freeze out in our modeled region within 70 *AU* around a sunlike star. However, the abundance of CO decreases because of the formation of complex organic molecules (COM), producing an effect that can be misinterpreted as the "snow line". These results are robust to variations in our assumptions about the evolution of the gas to dust ratio. The optical depths of low-order rotational lines of $C^{17}O$ are around unity, making it possible to see into the disk midplane using $C^{17}O$. Combining observations with modeled $C^{17}O/H_2$ ratios, like those we provide, can yield estimates of

protoplanetary disks' gas masses.

Accepted by ApJ

http://arxiv.org/pdf/1603.08930v1

Feedback of the HBe star IL Cep on nearby molecular cloud and star formation

Si-Ju Zhang[1,2], Yuefang Wu[3], Jin Zeng Li[1], Jing-Hua Yuan[1], Hong-Li Liu[1,2], Xiaoyi Dong[3] and Ya-Fang Huang[1]

[1] National Astronomical Observatories, Chinese Academy of Sciences, 20A Datun Road, Chaoyang District, Beijing 100012, China
[2] University of Chinese Academy of Science, Beijing 100049, China
[3] Department of Astronomy, Peking University, 100871 Beijing, China; ywu@pku.edu.cn

E-mail contact: sjzhang *at* nao.cas.cn

We present investigations of the feedback of a luminous Herbig Be star, IL Cep. We mapped the vicinity of IL Cep in the J=1-0 transitions of ^{12}CO, ^{13}CO and C^{18}O molecular lines with the *Purple Mountain Observatory* 13.7 m telescope. Archival data from *Wide-field Infrared Survey Explorer* were also employed. A parsec–scale cavity that has probably been excavated by the dominant HBe star, IL Cep, is revealed. An expanding shell-like structure featured by ^{12}CO(J=1-0) emission was found surrounding the cavity, which embeds several ^{13}CO(J=1-0) molecular clumps. The density and velocity gradients imply strong stellar winds from exciting stars, this is consistent with the morphology of molecular cloud. The ^{12}CO(J=1-0) spectra show broad blue wings with a width of about 3.5 km s^{-1}. We suggest that the broad blue wings could be emission from the molecular gas shocked by stellar winds, while the main narrow component may originate from pre-shocked gas. Several bright bow–shaped rims have been detected at 12 μm, which serve as the interface of the molecular cloud facing UV dissipation from the exciting stars. The rims all have an orientation facing IL Cep, this may indicate the predominant effects of IL Cep on its surroundings. A very young star candidate (about $10^{4.8}$ yr) was found in the head of one bright rim, but its triggered origin is uncertain. All results achieved in this paper suggest that IL Cep has violent effects on its surroundings.

Accepted by MNRAS

https://www.researchgate.net/publication/298424571

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.

Abstracts of recently accepted major reviews

Gravitational Instabilities in Circumstellar Disks

Kaitlin M. Kratter[1] **and Giuseppe Lodato**[2]

[1] University of Arizona, USA
[2] Università degli Studi di Milano, Italy

E-mail contact: kkratter@email.arizona.edu

[Abridged] Star and planet formation are the complex outcomes of gravitational collapse and angular momentum transport mediated by protostellar and protoplanetary disks. In this review we focus on the role of gravitational instability in this process. We begin with a brief overview of the observational evidence for massive disks that might be subject to gravitational instability, and then highlight the diverse ways in which the instability manifests itself in protostellar and protoplanetary disks: the generation of spiral arms, small scale turbulence-like density fluctuations, and fragmentation of the disk itself. We present the analytic theory that describes the linear growth phase of the instability, supplemented with a survey of numerical simulations that aim to capture the non-linear evolution. We emphasize the role of thermodynamics and large scale infall in controlling the outcome of the instability. Despite apparent controversies in the literature, we show a remarkable level of agreement between analytic predictions and numerical results. We highlight open questions related to (1) the development of a turbulent cascade in thin disks, and (2) the role of mode-mode coupling in setting the maximum angular momentum transport rate in thick disks.

Accepted by ARAA

http://arxiv.org/pdf/1603.01280

Insights into planet formation from debris disks: I. The solar system as an archetype for planetesimal evolution

Brenda C. Matthews[1,2] **and J.J. Kavelaars**[1,2]

[1] National Research Council of Canada, 5071 West Saanich Road, Victoria, BC, V9E 2E7 Canada
[2] University of Victoria, Finnerty Road, Victoria, BC V8W 3P6, Canada

E-mail contact: brenda.matthews *at* nrc-cnrc.gc.ca

Circumstellar disks have long been regarded as windows into planetary systems. The advent of high sensitivity, high resolution imaging in the submillimetre where both the solid and gas components of disks can be detected opens up new possibilities for understanding the dynamical histories of these systems and therefore, a better ability to place our own solar system, which hosts a highly evolved debris disk, in context. Comparisons of dust masses from protoplanetary and debris disks have revealed a stark downturn in mass in millimetre-sized grains around a stellar age of 10 Myr, ostensibly in the "transition disk" phase, suggesting a period of rapid accretion of such grains onto planetesimals. This rapid formation phase is in keeping with radionucleide studies of Kuiper Belt Objects in the solar system. Importantly, this suggests that any thermal gradients in the gas of disks of this era will be "frozen in" to the planetesimals as they rapidly accrete from the solids and ices in their vicinity. Measurements of radial gradients in thermal tracers such as DHO, DCN and other tracers can therefore provide insight into the nascent solar system's abudances. In studies of dynamical evolution of the solar system, it is tacitly assumed that such abundances can reveal the location of formation for bodies now found in the asteroid belt and Kuiper belt. Similarly, evidence of gas detected from collisional evolution in young debris disks could potentially reveal how rapidly objects have dynamically evolved in those systems, most of which will be significantly younger than the solar system.

Accepted by Space Science Reviews

http://arxiv.org/pdf/1603.06645

Insights into planet formation from debris disks: II. Giant impacts in extrasolar planetary systems

M. C. Wyatt[1] and A. P. Jackson[2]

[1] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK
[2] School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, USA

E-mail contact: wyatt *at* ast.cam.ac.uk

Giant impacts refer to collisions between two objects each of which is massive enough to be considered at least a planetary embryo. The putative collision suffered by the proto-Earth that created the Moon is a prime example, though most Solar System bodies bear signatures of such collisions. Current planet formation models predict that an epoch of giant impacts may be inevitable, and observations of debris around other stars are providing mounting evidence that giant impacts feature in the evolution of many planetary systems. This chapter reviews giant impacts, focussing on what we can learn about planet formation by studying debris around other stars. Giant impact debris evolves through mutual collisions and dynamical interactions with planets. General aspects of this evolution are outlined, noting the importance of the collision-point geometry. The detectability of the debris is discussed using the example of the Moon-forming impact. Such debris could be detectable around another star up to 10Myr post-impact, but model uncertainties could reduce detectability to a few 100yr window. Nevertheless the 3% of young stars with debris at levels expected during terrestrial planet formation provide valuable constraints on formation models; implications for super-Earth formation are also discussed. Variability recently observed in some bright disks promises to illuminate the evolution during the earliest phases when vapour condensates may be optically thick and acutely affected by the collision-point geometry. The outer reaches of planetary systems may also exhibit signatures of giant impacts, such as the clumpy debris structures seen around some stars.

Accepted by Space Science Reviews

http://arxiv.org/pdf/1603.04857

New Jobs

Post-doctoral position available

A post-doctoral position is available within the star formation and masers group of the Centre for Space Research of the North-West University, South Africa. The current focus of this group is on periodic masers associated with high-mass star forming regions, in particular to understand what mechanism(s) underlie the periodicity and how the periodic masers can help to better understand the environment of very young high-mass stars. Applicants should have experience in observational and/or theoretical research in high-mass star formation, astrochemistry, or astrophysical masers associated with high-mass star forming regions. Applicants must have a recent PhD in either Astrophysics or Astronomy. For more information please contact the programme-leader Prof. Johan van der Walt (johan.vanderwalt@nwu.ac.za) directly.

Linking Exoplanet and Disk Compositions workshop @ Space Telescope Science Institute September 12-14, 2016

This workshop will gather scientists working on the compositional characterization of planets and planet-forming regions in protoplanetary disks. Recent and upcoming advancements make it timely to have a round-table conversation among the several communities involved, to join forces in tackling our most compelling questions on the origins of exoplanet diversity. Do exoplanet compositions retain the imprint of large-scale disk processes? Do disks include compositional trends that imprint on planets? What do we learn in this context from observations of Solar System bodies? And what can we test with observations of disks and exoplanets in the near future? We intend to identify long-lasting and observable links between exoplanet and disk compositions, to help the community in shaping ongoing modeling efforts as well as the essential parameter space to cover with existing and upcoming observatories for exoplanet and disk characterization.

Pre-registration and abstract submission are now open: http://www.cvent.com/d/ffqwn1

Please check the preliminary schedule available on the website for details on invited talks and workshop sessions.

Invited Speakers: Conel Alexander (Carnegie DTM), Uma Gorti (SETI, NASA Ames), Mike Line (Arizona State), Jonathan Lunine (Cornell Univ.), Christoph Mordasini (Univ. of Bern), Ilaria Pascucci (Univ. of Arizona), Sean Raymond (Univ. of Bordeaux), Leslie Rogers (Univ. of Chicago)

SOC: Daniel Apai (Univ. of Arizona), Andrea Banzatti (STScI, chair), Fred Ciesla (Univ. of Chicago), Jonathan Fortney (UCSC), Sarah Horst (JHU), Inga Kamp (Kapteyn Inst. Groningen), Nikole Lewis (STScI, co-chair), Amaya Moro-Martin (STScI), Karin Oberg (Harvard CfA), Klaus Pontoppidan (STScI), Olivia Venot (Katholieke Univ. Leuven), Marie Ygouf (STScI)

For questions and inquiries, please feel free to contact us at: exodisks@stsci.edu

Interstellar shocks: models, observations & experiments
Toruń, Poland, 14th - 16th September 2016

Shocks are ubiquitous in the interstellar medium, including protostars, evolved stars, supernovae blast waves as well as spiral arms. On small scales, shocks have a strong impact on the local physical conditions, the gas chemistry and they deeply affect dust grains, through sputtering of their ice mantle or their refractory cores, or even through shattering in the fastest shocks. On larger scales, shocks produced by spiral arms can induce colliding flows, triggering the formation of molecular clouds. The cumulative impact of shocks influence the evolution of molecular clouds by injecting supersonic turbulence, and in turn their star formation efficiency, hence play a major role in regulating the star formation rate of galaxies. Shocks are therefore relevant for many astrophysical and chemical processes and their detailed understanding, which needs a combination of observations, models and laboratory experiments, has a wide range of applications.

This meeting will cover all aspects of shocks in the interstellar medium: from microphysics to impact on galaxy scales. The program of the workshop includes: observations of shocks and related chemistry in protostars, supernovae remnants and evolved stars from UV to sub-mm. Models of shocks with a special focus on the impact of UV irradiation, the shock geometry, and the role of grains, laboratory studies of shocks, jets and sputtering phenomenon, and shocks in stellar cluster and at molecular cloud scales.

Organisers: Maryvonne Gerin (Observatoire de Paris, FR) and Agata Karska (Adam Mickiewicz University, Poznań, PL)

Invited speakers: Sybille Anderl, Hector Arce, Sylvie Cabrit, Andrea Ciardi, Antoine Gusdorf, Michael Kaufman, Ralf Klessen, Lars Kristensen, David Neufeld, John Raymond, Steven Sibener, Mario Tafalla

Deadline for abstract submission: May 1st, 2016

Website: http://shocks2016.faj.org.pl/

Contact: shocks2016@faj.org.pl

Summary of Upcoming Meetings

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

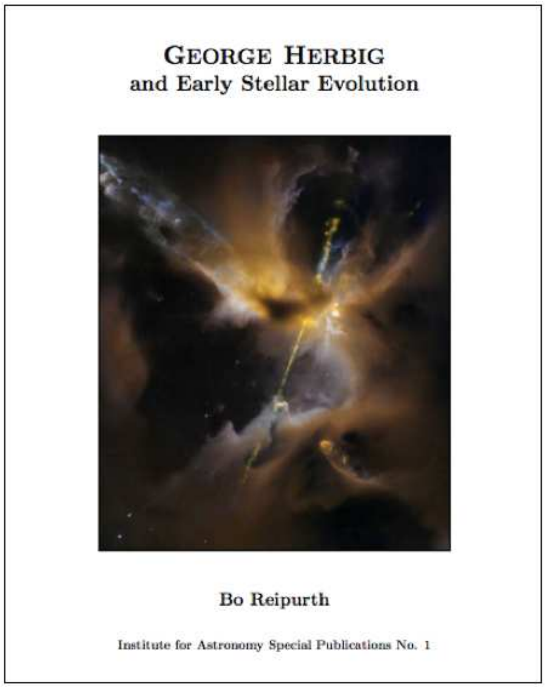
Search for life: from early Earth to exoplanets
12 - 16 December 2016, Quy Nhon, Vietnam
http://rencontresduvietnam.org/conferences/2016/search-for-life

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

New Books

George Herbig and Early Stellar Evolution

Bo Reipurth



When George Herbig passed away in October 2013 at the age of 93, astronomy lost one of the great figures of 20th century astronomy. Herbig largely built the foundation on which much of our present-day understanding of low-mass star formation is based. This new book presents a scientific biography of Herbig and discusses the circumstances of his main achievements and puts them into the context of current results.

The following lists the chapters of the book:

1 The Budding Astronomer
2 T Tauri Stars
3 Herbig-Haro Objects
4 The Herbig Ae/Be Stars
5 FUors and EXors
6 Clustered Star Formation
7 The Interstellar Medium
8 Molecular Spectroscopy
9 Variable and Exotic Stars
10 From Astronomer to Professor
11 Instruments and Telescopes
12 Closing Remarks

Institute for Astronomy Special Publications No. 1, 257 pages, 2016
Available at no cost from http://ifa.hawaii.edu/SP1