THE STAR FORMATION NEWSLETTER

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

No. 267 — 12 March 2015 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)

The Star Formation Newsletter

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

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Cover Picture

CG 12 is a major cometary globule located in Centaurus. It is a relatively high-latitude cloud ($b = 21.1°$), which at the estimated distance of 550 pc corresponds to about 200 pc above the Galactic plane. The reflection nebula NGC 5367, discovered by John Herschel in 1834, is illuminated by the visual binary h4636. The northern component is a Herbig Ae/Be star (spectral type B4), while the southern component appears to be a normal-looking B7 star. More than 50 PMS stars are associated with the globule, either as Hα emission stars or X-ray sources (Getman et al. 2008). The tail of the globule is about 1 degree long, and it appears that an energetic event triggered the star formation in the globule. Since the globule faces away from the Galactic plane, this unknown event must have taken place at even higher Galactic latitude. South is up and east is right.

Image courtesy Velimir Popov and Emil Ivanov, IRIDA Observatory
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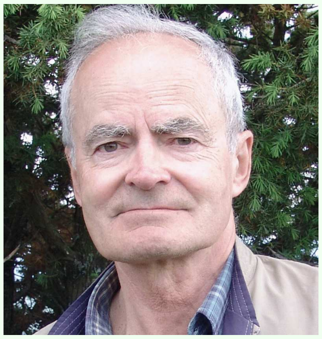
Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each Call for Abstracts. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/star-formation/index.cfm

Peter Petrov

in conversation with Bo Reipurth



Q: *How did you get interested in astronomy?*

A: My fascination with astronomy started in childhood: I was born in a small village in Siberia, where the dark winter sky was shining with myriads of stars, like in a desert. My first book on astronomy was purchased in 1955, just before the first satellite 'Sputnik' was launched. Later, astronomy became very popular in the Soviet Union. I graduated from the Ural State University and got a position at the Crimean Astrophysical Observatory (CrAO) in 1968.

Q: *You studied T Tauri stars for your PhD. How did that come about?*

A: Solar and stellar magnetic activity were the main directions of research at CrAO. In the department of stellar physics, headed by Prof. Vladimir Nikonov, I was encouraged to study the Orion irregular variables, now called T Tauri stars. The idea was that magnetic activity of solar type (sunspots, chromospheric flares, and winds) could be scaled up to explain the observed activity of T Tauri stars, although no direct measurements of magnetic fields in those stars were done up to that time.

My PhD work was devoted to photometric variability of T Tauri stars. It was defended in 1976 at the Leningrad State university, in Sobolev's department. Then I switched to spectroscopic studies of T Tauri stars. The first CCD detectors became available at CrAO only in 1985. Before that I tried to use the Electronographic Image Converter, a big and heavy device, with 40 kilovolt tension on the back side, just in front of the observer's face. After solving many technical problems, I succeeded to get a series of spectra of RW Aur. From that series we discovered a rotational modulation of the Balmer emission line profiles with a period of 5.4 days. It was the first indication that an axially asymmetric magnetic field governs the wind flows. The work was done in collaboration with Vladimir Grinin, who modeled the wind line profiles.

Another odd feature often observed in spectra of RW Aur was the progressive change in Balmer lines profiles, from outflow in Hα to inflow in Hγ and Hδ. How could it be that inflow and outflow co-exist along the same line of sight to that star? The answer came only a decade later, when in a famous paper in 1991 Arieh Königl applied the magnetospheric accretion model to T Tauri stars.

Interestingly, in March 1979 I happened to obtain one spectrum of RW Aur which showed pronounced red-shifted absorptions in many lines of metals – a clear indication of accretion! The velocity of the infalling gas reached 300-400 km/s, close to the free-fall velocity. I presented this spectrum at a meeting in Armenia in 1980, where Victor Ambartsumyan was present. He was rather skeptical about the accretion ideas, but respected observational results. "Very interesting" - he said.

Q: *You have had extensive collaborations with colleagues in the western world.*

A: My scientific collaboration with the western community was initiated by Gösta Gahm, who visited Crimean Observatory in 1975. Since that time we have had many joint projects dealing with observational studies of T Tauri stars, mainly with the Nordic Optical Telescope. I also appreciate very much the scientific and friendly ties with Portuguese colleagues. In 1985, Prof. Teresa Lago invited me to give a short course of lectures for her students at the newly established Center for Astrophysics at the University of Porto (CAUP).

The 1990's were the most difficult period in our country. At that time, a dozen Crimean astronomers went abroad, to Europe and USA. I am very grateful to Prof. Ilkka Tuominen who offered me a job in Finland, at Helsinki Observatory and the University of Oulu. Ilkka headed a small group working on magnetic activity of stars, including T Tauri stars. Except for teaching duties, we were involved in observations with the new high-resolution echelle spectrograph called SOFIN (SOvietFINnish). The SOFIN instrument was a successful product of collaboration between Crimean and Finnish astronomers. The spectrograph was installed at the Nordic Optical Telescope in 1992. By 1993 we had already obtained series of high quality spectra of T Tauri stars. The process of observations was not completely automated, so we had to travel to La Palma, which was the most enjoyable part of the projects. Astronomy gave me the possibility to travel over the world.

Q: *You have published a series of papers on FU Ori. What initiated that?*

A: In 1984 I traveled across USA, from Washington DC to California, visiting CfA, Tucson, Kitt Peak, Mt. Hopkins, and the Mt. Wilson, Mt. Palomar and Lick observatories. That was really a great experience for me, both scientifically and culturally. I keep very good memories of the hospitality of Bill Livingston, David Latham, George and Hannelore Herbig, and many others who took care of me during that time. The visit was arranged within the scientific exchange program between the USSR and USA academies of sciences. The mid of the 1980s was at the peak of the cold war, and I was very surprised to see how friendly Americans were to the Russian visitor, not only in a scientific community but also the people on the streets I met every day. The final point of destination was Santa Cruz and Lick observatory, where I worked with George Herbig during two months. George suggested to measure the photographic and CCD spectra of FU Ori, taken by him at Lick Observatory. He said there was something strange with the photospheric line profiles: most of the lines looked double, like in a spectroscopic binary consisting of two identical G-supergiants. Of course, the hypothesis of a binary was weak: only one star could flare up by six magnitudes, not both. After careful analysis of the spectra we ended up with two hypotheses: either there were emission components present at the bottom of the broad photospheric lines, or the lines are formed in a luminous accretion disk. That result was not published immediately, however, since we planned to take one more spectrum. On the way back home I visited CfA and talked to Lee Hartmann about this effect of line doubling. Lee has recently written about this in his reminiscences in Star Formation Newsletter 260.

The accretion disk model of FUors is based mostly on the spectral energy distribution over a broad wavelength range, which undoubtedly belongs to a self-luminous disk. The difference in the optical and infrared line widths indicates the differential rotation of the inner and outer disk areas. In the work with George Herbig we focused on the *optical* spectrum of FUors, which belongs to the central object, whatever it was - a star or the innermost region of an accretion disk close to the star. It is interesting to note, that originally the argument in support of the accretion disk model was the dependence of the photospheric line width on wavelength and excitation potential of a line, as it was expected for a differentially rotating disk with a temperature decreasing outward. However, using the best quality CCD spectra of FU Ori, we did not find such a dependence within 4500-8000 A.

In our last paper with George Herbig in 2008 we analysed high-quality Keck/HIRES spectra of FU Ori which revealed fine structures in the broad photospheric lines. It may be a coincidence that these specific fine structures are well reproduced in a model of a spherical object with a dark polar area. Regardless of the physical interpretation, this may be an indication of the *geometry* of the photosphere.

These may all be unimportant details in the global aspect of the accretion disc model, but "the devil is in the details".

Q: *You have long been interested in the veiling of T Tauri stars.*

A: I believe that the veiling phenomenon is still not deeply understood. It is widely accepted that veiling of the photospheric spectrum of classical T Tauri stars is due to continuum radiation from the hot spots at the base of accretion channels. However, when the veiling is measured carefully in every single spectral line within a narrow wavelength range, it turns out that the veiling factor depends on strength of the line in a template of the corresponding spectral type. Stronger lines can be veiled considerably, while the weakest lines remain about normal for the spectral type. This is probably the chromospheric effect: the upper layers of atmosphere are heated up by a "shower" of the accreting matter. The effect is best detected in T Tauri stars with low $v \sin i$, where equivalent widths of the weakest photospheric lines (a few mÅ) can be measured. So far we studied this phenomenon in two stars, DR Tau and V1331 Cyg. It is worthwhile to continue this work with a sample of high quality spectra of classical T Tauri stars with different rates of mass accretion.

Q: *What are you currently working on?*

A: This last year we published two interesting results. We have studied the wind dynamics of the so-called "pre-FUors" - T Tauri stars with the top mass-loss rates, a few times 10^{-7} $M_{\odot}$/yr. The first target was V1331 Cyg. We found that the star is a rare case of a T Tauri star seen down along its jet, which is directed exactly toward the observer. In this specific case the observed P Cyg absorption in the Balmer lines can be formed only in a stellar wind, because the line of sight to the star does not intersect either a disk-wind or the accretion-driven conical wind. Then the question arises: what is the acceleration mechanism for the wind? How can a stellar wind drive such a high mass?

Another publication was devoted to the magnetospheric accretion in S CrA. In one of the spectra, taken at the ESO VLT in 2005, inversed P Cyg absorption was present in many lines of metals, including FeI, FeII, SiII and others. For the first time we restored the temperature and density profiles along the accretion channel down to the stellar surface.

Now we got a new surprise: a few months ago, at the end of 2014, RW Aur went into a deep minimum. Its primary component became fainter than the secondary. We keep tracking the star.

Perspective

Star and Planet Formation in Clusters

Fred Adams

1 Introduction

The current consensus holds that most stars are born within stellar clusters of some variety (e.g., Lada & Lada 2005, Porras et al. 2003, Allen et al. 2007). At the same time, the overall planet occurrence rate is quite high, with more than 26% of Sun-like stars having small planets within 0.4 AU (Marcy et al. 2014), so that the overall fraction of stars hosting planets is much higher. Although the jury is still out, it appears that most planets are also born within cluster environments. These developments thus lead to the overarching question: How does the cluster environment influence the formation and properties of the stars and planets produced within these astrophysical systems? This issue is important, both for the general question of how environments can sculpt forming planetary systems and for the specific question concerning the effects of our own birth cluster on the solar system (Adams 2010).

Although most researchers agree with the claim that most stars form in clusters, the ramifications of this idea are still being hammered out (e.g., compare the discussions of Hester et al. 2004, Williams & Gaidos 2007, Adams 2010, Williams 2010, Pfalzner 2013, and many others). This lack of convergence is due to a number of complexities associated with the problem, and the goal of this present discussion is to outline some of these complications.

For example, one issue is that the processes of cluster evolution, star formation, and planet formation all have a number of stages, and the way in which clusters affect star and planet formation depends on which stage is under consideration. In addition, the distribution of cluster membership sizes N, and other cluster properties, is wide. Clusters with different sizes and types have varying influences on their constituent solar systems. Finally, the effects of the cluster environment on forming star and planetary systems must be described in terms of distributions. A cluster does not affect every constituent solar system in the same way. Instead, a solar system will experience different types of influences sampled from a probability distribution.

Because of the set of complications outlined above — and many others — descriptions of the issues involved in star and planet formation within clusters require specificity. One must be clear about the type (and/or distribution) of cluster environments under consideration, the evolutionary stage of both the cluster and the young stellar objects of interest, the particular environmental effect under consideration, and so on. Further, for each such specification, the result must usually be described in terms of a probability distribution.

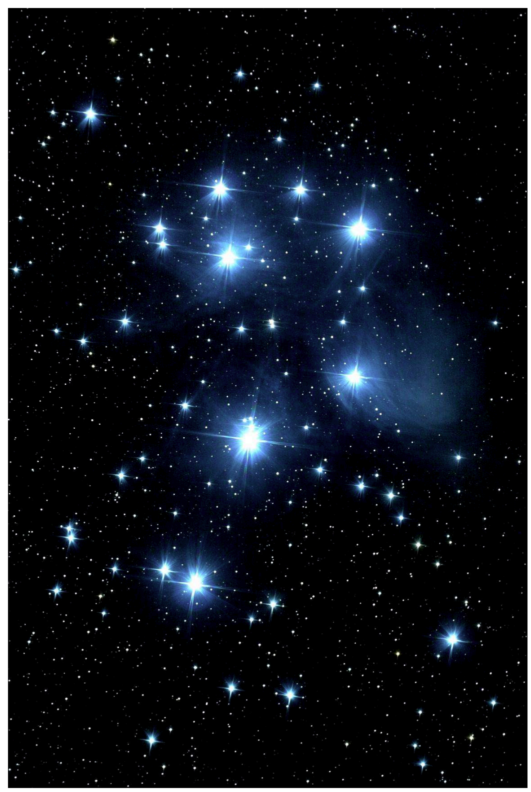


Figure 1: The Pleiades Open Cluster. Whereas most solar systems are born within embedded clusters of some type, only about ten percent of stars are born within clusters that are destined to become long-lived open clusters, such as the one shown here.

2 Effects of Clusters

The effects of clusters on star and planet formation can be broken up into the following classes:

Dynamics. Young stellar objects move within the cluster potential and can interact with each other. Such interactions can occur at varying stages of evolution (Shu et al. 1987), from protostellar cores, to star/disk systems, to binary and planetary systems. In the protostellar stage, the timescales are short and the speeds are slow (Peretto et al. 2006), so that minimal interaction takes place between separate cores, although significant interactions can take place within the cores. Somewhat later, newly formed stars are free to orbit within the gravitational potential of the cluster. The circumstellar disks can then be truncated through dynamical interactions (Ostriker 1994, Heller 1995), but can also gain additional mass by accreting cluster gas (Throop & Bally 2008). Most of the cluster residence time is thus spent when the stars have planetary systems and/or binary companions. During this stage, planets (Adams & Laughlin 2001) and stellar companions (Rasio et al. 1995) can be ejected, captured, and have their orbital elements modified (see also Spurzem et al. 2009, Dukes & Krumholz 2012, Picogna & Marzari 2014, Li & Adams 2015).

Radiation fields. Cluster environments provide a great deal of high energy radiation, which can influence their members. As one example, the typical ultraviolet flux level in a cluster is thousands of times higher than in the galaxy as a whole. These background radiation fields can be broken up into varying wavelength regimes, including FUV (Adams et al. 2006), EUV (Fatuzzo & Adams 2008), and X-rays (Adams et al. 2012). For star/disk systems, the radiation from the cluster environment often dominates that of the central star, primarily in the outer regions of the disk (Adams & Myers 2001, Thompson 2013). These external radiation fields provide an important source of ionization for circumstellar disks, and can also drive their evaporation, especially the FUV fields (Adams et al. 2004, Monga & Desch 2015).

Particle fluxes. In addition to electromagnetic radiation, clusters provide background fluxes of charged particles, from single protons to uranium nuclei. Such particle radiation contributes to both heating and ionization, which in turn affects chemistry, magnetic coupling, and other physical processes vital to star and planet formation. Compared to the background galaxy, clusters and their surrounding molecular clouds can produce either enhancements or deficits in the cosmic ray flux. Enhancements arise because supernovae are the source of cosmic rays and they explode within or near molecular clouds; the clouds are threaded by magnetic fields, which require the cosmic rays to random walk to escape the cloud, so that a short-term enhancement can be set up (Fatuzzo et al. 2006). On the other hand, the clusters and their constituent members also support magnetic fields, which can reduce the incoming flux of cosmic rays, both due to magnetic mirroring (Padovani & Galli 2011) and winds (Cleeves et al. 2013). On a related note, clusters, and the surrounding molecular cloud, can also be the source of short-lived radioactive nuclei, which are synthesized and distributed by supernovae. Decay of these nuclei provide a source of both heating and ionization to circumstellar disks (Umebayashi & Nakano 2009).

3 Evolutionary Stages

One can make the argument that clusters affect circumstellar disks and planet formation more than star formation itself (Adams 2010). Let's consider some of the cluster influences outlined above.

Dynamics: During the phase of protostellar collapse, the molecular cloud cores (or whatever you want to call the subunits that collapse to form individual stars) are observed to be moving slowly, typically at about half the sound speed (say 0.1 km/s). The collapse time is of order 0.1 Myr (Shu et al. 1987, McKee & Ostriker 2007), which implies that protostars move a distance of about 0.01 pc during their collapse phase. Given that this distance scale is much smaller than the distance between forming stars in a cluster (a few times 0.1 pc), dynamical interactions are minimal among protostars forming within different molecular cloud cores. At the same time, however, nontrivial interactions can take place within the cores, which often form multiple systems (binaries and triples). The ensuing complicated dynamics within these cores then contributes to the diversity we observe among embedded objects. In contrast, circumstellar disks live for millions of years, and planets form over comparable timescales; during these later stages, solar systems move near the virial speed of the cluster, typically $1-2$ km/s. As a result, solar systems move a factor of ~ 1000 farther than protostellar cores and have a commensurate increase in their chances of interacting.

Radiation: During the protostellar phase, star/disk systems are deeply embedded within optically thick envelopes of gas and dust, with visual extinctions $A_V = 10 - 100$, or even larger. These envelopes thus protect forming stars from background radiation of the cluster. Under extreme conditions, such radiation can help forming stars break out of their envelopes (Hester et al. 1996), but many environments are more benign. During the later phase of evolution, newly revealed star/disks systems have much lower values of A_V and are exposed to the background radiation of the cluster.

The claim considered here — that clusters affect forming planets more than forming stars — depends on how you define the start of the star formation process. Clusters certainly affect the production of the distributions of the initial conditions for protostellar collapse, i.e., the production of the pre-collapse subunits that make individual stars or binaries. Once a given protostellar collapse event is underway, however, the background cluster environment has relatively little effect on the object until the star/disk system is separated out from its collapsing envelope. The disk, and the planetary system it spawns, can then be more significantly affected by the background environment of the cluster.

4 Distributions of Properties

One of the complications associated with star formation in clusters is that these dynamical systems have a wide range of stellar membership sizes and other characteristics. These properties ultimately determine their evolution and lifetime, which play an important role in determining how much influence the clusters have on their constituent solar systems.

Although we do not yet have definitive determination of the cluster size distribution, a rough description can be given. The stellar inventories within these clusters ranges from $N = 1$ (for stars forming in isolation) up to about $N \sim 10^6$ (roughly the size of globular clusters). The distribution of sizes N can be described by a power-law, where the usual description has an index of 2, i.e., the form $d\psi/dN \propto N^{-2}$. This power-law form is observed for the clusters in the solar neighborhood (Lada & Lada 2003, Porras et al. 2003), where the range of N extends up to ~ 2000. The same form is observed farther away, for clusters in external galaxies (Elmegreen & Efremov 1997), where the values of N range from a few thousand up to $N \sim 10^6$. The usual assumption is that these power-laws match up, with the same normalization, so that the distribution is an unbroken power-law. Two things should be kept in mind for the present discussion: [1] significant uncertainties remain regarding the cluster size distribution, and [2] in spite of the aforementioned uncertainties, the distribution is wide, spanning approximately six decades in membership size.

Given the approximate power-law form $d\psi/dN \sim N^{-2}$ for the distribution of cluster sizes, the probability that a star will be born within a cluster of size N is given by $P \sim N(d\psi/dN) \sim N^{-1}$. Further, with this form, the fraction $f(N)$ of stars born within a cluster of size N or smaller is given by the cumulative probability $f(N) \sim \int P dN \sim \log N$ (see Figure 2). In other words, stars have approximately the same probability of being formed in clusters

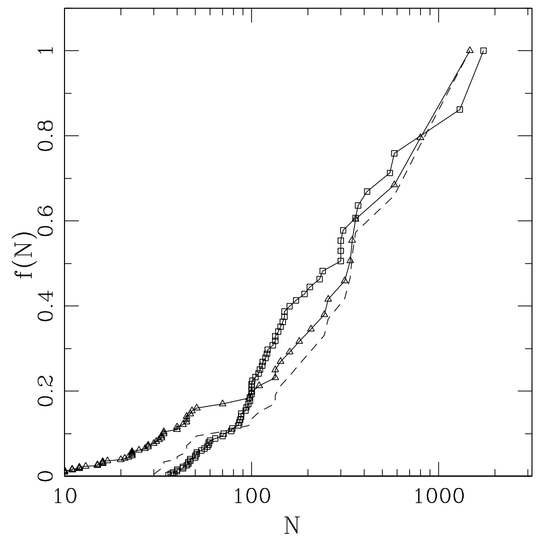


Figure 2: Cumulative probability $f(N)$ of stars that are born within clusters of stellar membership size N or smaller. Results are shown for two solar neighborhood cluster samples. The curve marked by squares uses data from Lada & Lada (2003) whereas the curve marked by triangles uses data from Porras et al. (2003). Note that $f(N) \propto \log N$.

within each decade of membership size N. With this result, and with six decades of cluster sizes, we find that 1/6th of the solar systems are born in small groups with $N = 1 - 10$ and the same fraction (about 1/6th) are born in rich clusters with $10^5 < N < 10^6$. Because of this diversity, and because rich clusters have different effects than small groups, it is difficult to make general statements about the "typical" birth environments for stars and planets.

This issue is subject to another complication: The largest clusters often have substructure in their initial configurations. Although these structures are eventually washed out after the cluster forms and relaxes dynamically, they nonetheless affect the early evolution (e.g., Allison et al. 2009). On the large scale, the cluster system can evolve as if the subclusters are the dynamical units, so that relaxation occurs more rapidly. On the smaller scales, stellar members within a subcluster are subject to the disruptive influences of their local environment more than the cluster as a whole. In this sense, even stars forming in rich clusters can be considered to be born within small clusters.

The results described above suggest that about half of all stars form in clusters with N in the range $10^3 < N < 10^6$.

On the other hand, another well-known result is that only about ten percent of all stars are born within systems that are destined to become long-lived open clusters (van den Bergh 1981, Battinelli & Capuzzo-Dolcette 1991), which remain gravitationally bound over timescales of 100 Myr to 1 Gyr. In order for both of these findings to hold, four out of five large clusters (those with starting sizes $N = 10^3 - 10^6$) must dissolve within a few tens of Myr so they will not appear as open clusters. This timescale is short — only of order 10 crossing times and much less than a single dynamical relaxation time. This issue thus poses an interesting open question: Why do 4 out of 5 young embedded clusters, with large stellar populations of $N = 10^3 - 10^6$, disappear so fast that they are not included in the open cluster sample? One interpretation is that most of these large (but short-lived) clusters are born expanding rapidly. Another interpretation is that some of these clusters are born with such low stellar densities that they quickly fade into the background of the galaxy. Although these positions allow for the clusters to disappear quickly, they pose a new question: In what sense are these systems really clusters? If a cluster system is born in a state of rapid expansion and/or low density, and lives for less than a dynamical relaxation time, the dynamics of the cluster — as an astrophysical system — are much different from the standard textbook description.

A related issue is that most discussions focus on star formation in clusters and ignore the distributed population (stars forming in effective isolation). The fraction of stars born outside of clusters is not well-determined by observations. Moreover, it is not clear that the total number of young stellar objects observed in embedded clusters is large enough to account for the global star formation rate of a galaxy. To date we have incomplete accounting.

5 Distributions of Cluster Effects

Clusters can have a wide range of properties, but even a given cluster does not affect all of its constituent members in exactly the same manner. As one example, consider the issue of disk evaporation. A given cluster will have a particular sample of the stellar initial mass function and will thus produce a collection of massive stars (that presumably live near the cluster center). These massive stars, in turn, produce intense UV radiation fields that can evaporate the circumstellar disks associated with other cluster members. However, at any given time, these other members will be dispersed across a distribution of radial positions and each will experience a different intensity of radiation. In addition, each star/disk system will trace through a different orbit inside the cluster. Some will plunge into the cluster core and will experience a great deal of radiation exposure. Others will safely orbit the outer reaches of the cluster and thereby escape strong radiation doses. The stellar mass, the disk properties, and the orientation will also affect the degree of destruction produced by the radiation. A large number of variables is thus involved in the problem. If we ask the seemingly well-posed question, "To what extent does cluster radiation evaporate the disks associated with its members?", a simple answer does not emerge. Instead, the cluster environment provides a distribution of UV radiation fields. This distribution, in conjunction with the distribution of orbits and other variables, jointly produce a distribution of possible effects. Some disks escape evaporation altogether, whereas others are severely truncated. This same complication arises when considering other possible channels through which clusters can affect their constituent solar systems.

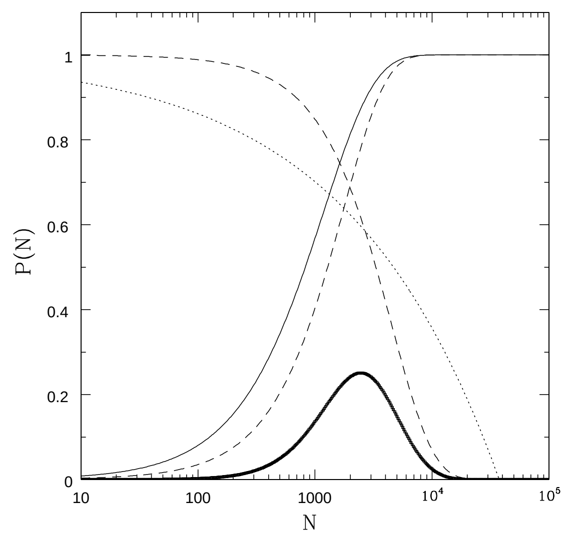


Figure 3: Probability of solar system disruption and survival versus cluster membership size N. The dotted curve shows the probability that a circumstellar disk will survive photoevaporation and retain a disk radius larger than $r_d = 30$ AU. The solid curve shows the probability that the cluster hosts a disruptive supernova explosion with progenitor mass $M_* > 25 M_\odot$. The dashed curves show the probability that the solar system *will* experience a scattering encounter within a distance of $b < 400$ AU (increasing curve) but will *not* experience an encounter with $b < 225$ AU (decreasing curve). The heavy solid curve shows the probability that all four conditions are met (adapted from Adams 2010).

To illustrate the manner in which clusters influence their constituent solar systems, we can find the probability of various potentially disruptive events as a function of the stellar membership size N. One example is shown in Figure 3, which shows the probability distributions for four types of cluster effects. The figure shows the probability of a circumstellar disk surviving the intense radiation fields provided by the cluster (dotted curve), where survival in this context corresponds to the absence of external photoevaporation inside $r_d = 30$ AU. Radiation fields tend to increase with the cluster membership, so that disk survival decreases with N. The figure also shows the probability of the cluster providing a large progenitor star with mass $M_* > 25 M_\odot$ (solid curve). Such large stars can explode as supernovae on sufficiently short time scales and disrupt disks (and perhaps seed them with radioactive nuclei). As shown, sufficiently large clusters (with $N > 3000$ or so) are highly likely to produce massive progenitors. Finally, the probability for close encounters are also indicated (see the dashed curves in Figure 3). The events described by the probability curves in Figure 3 were chosen because of their potential applicability to our own solar system (see Adams 2010). Analogous probability distributions can be (indeed should be) constructed to describe the disruption and/or survival of generic solar systems in cluster environments.

6 Conclusion

The bottom line is that clusters are complicated, so that any description of how the cluster environment affects star and planet formation must be constructed carefully. Clusters can potentially influence their constituent members through a variety of physical processes, including dynamical interactions, strong background radiation fields, and changes in cosmic ray fluxes. But the manner in which the clusters affect their constituent members depends on both the evolutionary state of the cluster and that of the young stellar object in question. Moreover, the influence of a cluster is not the same for all of the star/disk systems forming within it, and the effects must be described in terms of probability distributions.

This problem — the effects of clusters on star and planet formation — falls within an inconvenient part of parameter space: On one hand, cluster effects are too important to ignore. As one example, intense cluster radiation can evaporate disks and dynamical interactions can truncate disks; both of these processes can influence disk evolution. On the other hand, cluster effects do not completely change the processes of star and planet formation. For example, once a molecular cloud core is produced, its subsequent collapse follows the basic paradigm of isolated star formation. As another example, the frequency of planets inside and out of open clusters is observed to be the same (Meibom et al. 2013). As a result, we find that cluster effects are neither dominant nor negligible, but rather lie somewhere between these two extremes.

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Abstracts of recently accepted papers

Dust dynamics and evolution in expanding HII regions. I. Radiative drift of neutral and charged grains

V.V. Akimkin[1], M.S. Kirsanova[1], Ya. N. Pavlyuchenkov[1] and D.S. Wiebe[1]

[1] Institute of Astronomy of the Russian Academy of Sciences

E-mail contact: akimkin *at* inasan.ru

We consider dust drift under the influence of stellar radiation pressure during the pressure-driven expansion of an HII region using the chemo-dynamical model MARION. Dust size distribution is represented by four dust types: conventional polycyclic aromatic hydrocarbons (PAHs), very small grains (VSGs), big grains (BGs) and also intermediate-sized grains (ISGs), which are larger than VSGs and smaller than BGs. The dust is assumed to move at terminal velocity determined locally from the balance between the radiation pressure and gas drag. As Coulomb drag is an important contribution to the overall gas drag, we evaluate a grain charge evolution within the HII region for each dust type. BGs are effectively swept out of the HII region. The spatial distribution of ISGs within the HII region has a double peak structure, with a smaller inner peak and a higher outer peak. PAHs and VSGs are mostly coupled to the gas. The mean charge of PAHs is close to zero, so they can become neutral from time to time because of charge fluctuations. These periods of neutrality occur often enough to cause the removal of PAHs from the very interior of the HII region. For VSGs, the effect of charge fluctuations is less pronounced but still significant. We conclude that accounting for charge dispersion is necessary to describe the dynamics of small grains.

Accepted by MNRAS

http://arxiv.org/pdf/1502.06865

The Orion Fingers: Near-IR Adaptive Optics Imaging of an Explosive Protostellar Outflow

John Bally[1], Adam Ginsburg[2], Devin Silvia[3] and Allison Youngblood[4]

[1] Department of Astrophysical and Planetary Sciences, University of Colorado, UCB 389, Boulder, CO 80309, USA

[2] ESO Headquarters, Karl-Schwarzschild-Str. 2, 85748 Garching bei München, Germany

[3] NSF Astronomy and Astrophysics Postdoctoral Fellow, Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA

[4] Department of Astrophysical and Planetary Sciences, University of Colorado, UCB 389, Boulder, CO 80309, USA

E-mail contact: john.bally *at* colorado.edu

Adaptive optics images are used to test the hypothesis that the explosive BN/KL outflow from the Orion OMC1 cloud core was powered by the dynamical decay of a non-hierarchical system of massive stars. Narrow-band H_2, [Fe II], and broad-band K_s obtained with the Gemini South multi-conjugate adaptive optics (AO) system GeMS and near-infrared imager GSAOI are presented. The images reach resolutions of 0.08 to 0.10 arcsec, close to the 0.07 arcsec diffraction limit of the 8-meter telescope at 2.12 μm. Comparison with previous AO-assisted observations of sub-fields and other ground-based observations enable measurements of proper motions and the investigation of morphological changes in H_2 and [Fe II] features with unprecedented precision. The images are compared with numerical simulations of compact, high-density clumps moving $\sim 10^3$ times their own diameter through a lower density medium at Mach 10^3. Several sub-arcsecond H_2 features and many [Fe II] 'fingertips' on the projected outskirts of the flow show proper motions of $\sim$300 km/s. High-velocity, sub-arcsecond H_2 knots ('bullets') are seen as far as 140 arcsec from their suspected ejection site. If these knots propagated through the dense Orion A cloud, their survival sets a lower bound on their densities of order 10^7 cm^{-3}, consistent with an origin within a few au of a massive star and accelerated by a final multi-body dynamic encounter that ejected the BN object and radio source I from OMC1 about 500 years ago. Over 120 high-velocity bow-shocks propagating in nearly all directions from the OMC1 cloud core provide evidence for an explosive origin for the BN/KL outflow triggered by the dynamic decay of a non-hierarchical system of massive stars. Such events may be linked to the origin of runaway, massive stars.

Accepted by Astronomy & Astrophysics

http://arXiv.org/pdf/1502.04711

The MLP Distribution: A Modified Lognormal Power-Law Model for the Stellar Initial Mass Function

Shantanu Basu[1], M. Gil[1] and Sayantan Auddy[1]

[1] University of Western Ontario, London, Ontario, Canada

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

This work explores the mathematical properties of a distribution introduced by Basu & Jones (2004), and applies it to model the stellar initial mass function (IMF). The distribution arises simply from an initial lognormal distribution, requiring that each object in it subsequently undergoes exponential growth but with an exponential distribution of growth lifetimes. This leads to a modified lognormal with a power-law tail (MLP) distribution, which can in fact be applied to a wide range of fields where distributions are observed to have a lognormal-like body and a power-law tail. We derive important properties of the MLP distribution, like the cumulative distribution, the mean, variance, arbitrary raw moments, and a random number generator. These analytic properties of the distribution can be used to facilitate application to modeling the IMF. We demonstrate how the MLP function provides an excellent fit to the IMF compiled by Chabrier (2005) and how this fit can be used to quickly identify quantities like the mean, median, and mode, as well as number and mass fractions in different mass intervals.

Accepted by MNRAS

http://arxiv.org/pdf/1503.00023

Antifreeze in the hot core of Orion - First detection of ethylene glycol in Orion-KL

N. Brouillet[1,2], D. Despois[1,2], X.-H. Lu[3,4], A. Baudry[1,2], J. Cernicharo[5], D. Bockelée-Morvan[6], J. Crovisier[6], and N. Biver[6]

[1] Univ. Bordeaux, LAB, UMR 5804, F-33270 Floirac, France
[2] CNRS, LAB, UMR 5804, F-33270 Floirac, France
[3] Université de Toulouse, UPS-OMP, IRAP, Toulouse, France
[4] CNRS, IRAP, 9 Av. Colonel Roche, BP 44346, 31028 Toulouse Cedex 4, France
[5] Centro de Astrobiología (CSIC-INTA), Ctra de Torrejón a Ajalvir, km 4, 28850 Torrejón de Ardoz, Madrid, Spain
[6] LESIA, Observatoire de Paris, CNRS, UPMC, Universit Paris-Diderot, 5 place Jules Janssen, 92195 Meudon, France

E-mail contact: brouillet *at* obs.u-bordeaux1.fr

Comparison of their chemical compositions shows, to first order, a good agreement between the cometary and interstellar abundances. However, a complex O-bearing organic molecule, ethylene glycol $(CH_2OH)_2$, seems to depart from this correlation because it was not easily detected in the interstellar medium although it proved to be rather abundant with respect to other O-bearing species in comet Hale-Bopp. Ethylene glycol thus appears, together with the related molecules glycolaldehyde CH_2OHCHO and ethanol CH_3CH_2OH, as a key species in the comparison of interstellar and cometary ices as well as in any discussion on the formation of cometary matter. We focus here on the analysis of ethylene glycol in the nearest and best studied hot core-like region, Orion-KL. We use ALMA interferometric data because high spatial resolution observations allow us to reduce the line confusion problem with respect to single-dish observations since different molecules are expected to exhibit different spatial distributions. Furthermore, a large spectral bandwidth is needed because many individual transitions are required to securely detect large organic molecules. Confusion and continuum subtraction are major issues and have been handled with care. We have detected the aGg' conformer of ethylene glycol in Orion-KL. The emission is compact and peaks towards the Hot Core close to the main continuum peak, about $2''$ to the south-west; this distribution is notably different from other O-bearing species. Assuming optically thin lines and local thermodynamic equilibrium, we derive a rotational temperature of 145 K and a column density of 4.6×10^{15} cm^{-2}. The limit on the column density of the gGg' conformer is five times lower.

Accepted by A&A

http://arxiv.org/pdf/1502.03993

The JCMT Gould Belt Survey: SCUBA-2 observations of circumstellar disks in L1495

J.V. Buckle[1,2], E. Drabek-Maunder[3], J. Greaves[4], J.S. Richer[1,2], B.C. Matthews[5,6], D. Johnstone[7,5,6], H. Kirk[5], S.F. Beaulieu[8], D.S. Berry[7], H. Broekhoven-Fiene[6], M.J. Currie[7], M. Fich[8], J. Hatchell[9], T. Jenness[7,10], J.C. Mottram[11], D. Nutter[12], K. Pattle[13], J.E. Pineda[14,15], C. Salji[1,2], S. Tisi[8], J. Di Francesco[5,6], M.R. Hogerheijde[11], D. Ward-Thompson[13], P. Bastien[16], H. Butner[17], M. Chen[6], A. Chrysostomou[18], S. Coude[16], C.J. Davis[19], A. Duarte-Cabral[9], P. Friberg[7], R. Friesen[20], G.A. Fuller[15], S. Graves[7], J. Gregson[21,22], W. Holland[23,24], G. Joncas[25], J.M. Kirk[13], L.B.G. Knee[5], S. Mairs[6], K. Marsh[12], G. Moriarty-Schieven[5], J. Rawlings[26], E. Rosolowsky[27], D. Rumble[9], S. Sadavoy[28], H. Thomas[7], N. Tothill[29], S. Viti[30], G.J. White[21,22], C.D. Wilson[31], J. Wouterloot[7], J. Yates[26], M. Zhu[32]

[1] Astrophysics Group, Cavendish Laboratory, J J Thomson Avenue, Cambridge, CB3 0HE

[2] Kavli Institute for Cosmology, Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK

[3] Imperial College London, Blackett Laboratory, Prince Consort Rd, London SW7 2BB, UK

[4] Physics & Astronomy, University of St Andrews, North Haugh, St Andrews, Fife KY16 9SS, UK

[5] NRC Herzberg Astronomy and Astrophysics, 5071 West Saanich Rd, Victoria, BC, V9E 2E7, Canada

[6] Department of Physics and Astronomy, University of Victoria, Victoria, BC, V8P 1A1, Canada

[7] Joint Astronomy Centre, 660 N. A'ohōkū Place, University Park, Hilo, Hawaii 96720, USA

[8] Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1

[9] Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK

[10] Department of Astronomy, Cornell University, Ithaca, NY 14853, USA

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

[12] School of Physics and Astronomy, Cardiff University, The Parade, Cardiff, CF24 3AA, UK

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

[14] European Southern Observatory (ESO), Garching, Germany

[15] Jodrell Bank Centre for Astrophysics, Alan Turing Building, School of Physics and Astronomy, University of Manchester, Oxford Road, Manchester, M13 9PL, UK

[16] Université de Montréal, Centre de Recherche en Astrophysique du Québec et département de physique, C.P. 6128, succ. centre-ville, Montréal, QC, H3C 3J7, Canada

[17] James Madison University, Harrisonburg, Virginia 22807, USA

[18] School of Physics, Astronomy & Mathematics, University of Hertfordshire, College Lane, Hatfield, HERTS AL10 9AB, UK

[19] Astrophysics Research Institute, Liverpool John Moores University, Egerton Warf, Birkenhead, CH41 1LD, UK

[20] Dunlap Institute for Astronomy & Astrophysics, University of Toronto, 50 St. George St., Toronto ON M5S 3H4 Canada

[21] Dept. of Physical Sciences, The Open University, Milton Keynes MK7 6AA, UK

[22] The Rutherford Appleton Laboratory, Chilton, Didcot, OX11 0NL, UK

[23] UK Astronomy Technology Centre, Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK

[24] Institute for Astronomy, Royal Observatory, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, UK

[25] Centre de recherche en astrophysique du Quebec et Département de physique, de génie physique et d'optique, Université Laval, 1045 avenue de la médecine, Québec, G1V 0A6, Canada

[26] Department of Physics and Astronomy, UCL, Gower St, London, WC1E 6BT, UK

[27] Department of Physics, University of Alberta, Edmonton, AB T6G 2E1, Canada

[28] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany

[29] University of Western Sydney, Locked Bag 1797, Penrith NSW 2751, Australia

[30] Department of Physics and Astronomy, University College London, Gower Street, London, UK, WC1E 6BT

[31] Department of Physics and Astronomy, McMaster University, Hamilton, ON, L8S 4M1, Canada

[32] National Astronomical Observatory of China, 20A Datun Road, Chaoyang District, Beijing 100012, China

E-mail contact: j.buckle *at* mrao.cam.ac.uk

We present 850 μm and 450 μm data from the JCMT Gould Belt Survey obtained with SCUBA-2 and characterise the dust attributes of Class I, Class II and Class III disk sources in L1495. We detect 23% of the sample at both wavelengths, with the detection rate decreasing through the Classes from I–III. The median disk mask is 1.6×10^{-3} $M_{\odot}$, and only 7% of Class II sources have disk masses larger than 20 Jupiter masses. We detect a higher proportion of disks towards sources with stellar hosts of spectral type K than spectral type M. Class II disks with single stellar hosts of spectral type K have higher masses than those of spectral type M, supporting the hypothesis that higher mass stars have more massive disks. Variations in disk masses calculated at the two wavelengths suggests there may be differences in dust opacity and/or dust temperature between disks with hosts of spectral types K to those with spectral type M.

Accepted by MNRAS

http://arxiv.org/pdf/1502.07946

Near-IR imaging of T Cha: evidence for scattered-light disk structures at solar system scales

A. Cheetham[1], N. Huélamo[2], S. Lacour[3], I. de Gregorio-Monsalvo[4,5], and P. Tuthill[1]

[1] Sydney Institute for Astronomy, School of Physics, University of Sydney, NSW 2006, Australia
[2] Centro de Astrobiología (INTA-CSIC); ESAC Campus, P.O. Box 78, E-28691 Villanueva de la Cañada, Spain
[3] Observatoire de Paris, LESIA/CNRS UMR, 5 place Jules Janssen, Meudon, France
[4] Joint ALMA Observatory (JAO), Alonso de Cordova 3107, Vitacura, Santiago de Chile
[5] European Southern Observatory, Garching bei Munchen, D-85748 Germany

E-mail contact: a.cheetham *at* physics.usyd.edu.au

T Chamaeleontis is a young star surrounded by a transitional disk, and a plausible candidate for ongoing planet formation. Recently, a substellar companion candidate was reported within the disk gap of this star. However, its existence remains controversial, with the counter-hypothesis that light from a high inclination disk may also be consistent with the observed data. The aim of this work is to investigate the origin of the observed closure phase signal to determine if it is best explained by a compact companion. We observed T Cha in the L' and K_s filters with sparse aperture masking, with 7 datasets covering a period of 3 years. A consistent closure phase signal is recovered in all L' and K_s datasets. Data were fit with a companion model and an inclined circumstellar disk model based on known disk parameters: both were shown to provide an adequate fit. However, the absence of expected relative motion for an orbiting body over the 3-year time baseline spanned by the observations rules out the companion model. Applying image reconstruction techniques to each dataset reveals a stationary structure consistent with forward scattering from the near edge of an inclined disk.

Accepted by MNRAS Letters

http://arxiv.org/pdf/1502.05084

VLT near- to mid-IR imaging and spectroscopy of the M17 UC1-IRS5 region

Zhiwei Chen[1,2,3], Dieter E. A. Nuernberger[2], Rolf Chini[2,4], Zhibo Jiang[1] and Min Fang[1]

[1] Purple Mountain Observatory, CAS, Nanjing, China
[2] Astronomical institute of Ruhr-University Bochum, Germany
[3] University of Chinese Academy of Sciences, 100039 Beijing, China
[4] Instituto de Astronomia, Universidad Catolica del Norte, Avenida Angamos 0610, Casilla 1280 Antofagasta, Chile

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

We investigate the surroundings of the hypercompact H II region M 17 UC1 to probe the physical properties of the associated young stellar objects and the environment of massive star formation. We use diffraction-limited near-IR (VLT/NACO) and mid-IR (VLT/VISIR) images to reveal the different morphology at various wavelengths. Likewise we investigate the stellar and nebular content of the region by VLT/SINFONI integral field spectroscopy with a resolution $R \sim 1500$ at $H + K$ bands. Five of the seven point sources in this region show L-band excess emission. Geometric match is found between the H_2 emission and near-IR polarized light in the vicinity of IRS5A, and between the diffuse mid-IR emission and near-IR polarization north of UC1. The H_2 emission is typical for dense PDRs, which are FUV pumped initially and repopulated by collisional de-excitation. The co-presence of He I, H I, and H_2

lines in most region argues against an edge-on configuration of the M 17 SW PDR, but is in favor of a moderately inclined geometry with respect to the line of sight. The spectral types of IRS5A and B273A are B3−B7 V/III and G4−G5 III, respectively. The observed infrared luminosity $L_{\rm IR}$ in the range $1-20\,\mu$m is derived for three objects; we obtain $2.0\times10^3\,L_\odot$ for IRS5A, $13\,L_\odot$ for IRS5C, and $10\,L_\odot$ for B273A. IRS5 might be a young quadruple system. Its primary star IRS5A is confirmed to be a high-mass protostellar object ($\sim 9\,M_\odot, \sim 1\times10^5$ yrs); it might have terminated accretion due to the feedback from the stellar activities (radiation pressure, outflow) and the expanding H II region of M 17. UC1 might also have terminated accretion because of the expanding hypercompact H II region ionized by itself. The disk clearing process of the low-mass YSOs in this region might be accelerated by the expanding H II region. The outflows driven by UC1 are running in south-north with its northeastern side suppressed by the expanding ionization front of M 17; the blue-shifted outflow lobe of IRS5A is seen in two types of tracers along the same line of sight in the form of H_2 emission filament and mid-emission. The H_2 line ratios probe the properties of M 17 SW PDR, which is confirmed to have a clumpy structure with two temperature distributions: warm, dense molecular clumps with $n_{\rm H} > 10^5\,{\rm cm^{-3}}$ and $T \approx 575$ K and cooler atomic gas with $n_{\rm H} \sim 3.7\times10^3 - 1.5\times10^4\,{\rm cm^{-3}}$ and $T \sim 50-200$ K.

Accepted by A&A

http://arxiv.org/pdf/1502.04959

Volatile Delivery to Planets from Water-rich Planetesimals around Low Mass Stars

Fred J. Ciesla[1], Gijs D. Mulders[2], Ilaria Pascucci[2], and Dániel Apai[2]

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

[2] Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA

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

Most models of volatile delivery to accreting terrestrial planets assume that the carriers for water are similar in water content to the carbonaceous chondrites in our Solar System. Here we suggest that the water content of primitive bodies in many planetary systems may actually be much higher, as carbonaceous chondrites have lost some of their original water due to heating from short-lived radioisotopes that drove parent body alteration. Using N-body simulations, we explore how planetary accretion would be different if bodies beyond the water line contained a water mass fraction consistent with chemical equilibrium calculations, and more similar to comets, as opposed to the more traditional water-depleted values. We apply this model to consider planet formation around stars of different masses and identify trends in the properties of Habitable Zone planets and planetary system architecture which could be tested by ongoing exoplanet census data collection. Comparison of such data with the model predicted trends will serve to evaluate how well the N-body simulations and the initial conditions used in studies of planetary accretion can be used to understand this stage of planet formation.

Accepted by ApJ

http://arxiv.org/pdf/1502.07412

Investigating the Global Collapse of Filaments Using Smoothed Particle Hydrodynamics

Seamus D. Clarke[1] and Anthony P. Whitworth[1]

[1] School of Physics and Astronomy, Cardiff University, Cardiff, CF24 3AA, UK

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

We use Smoothed Particle Hydrodynamic simulations of cold, uniform density, self-gravitating filaments, to investigate their longitudinal collapse timescales; these timescales are important because they determine the time available for a filament to fragment into cores. A filament is initially characterised by its line-mass, $\mu_{\rm O}$, its radius, $R_{\rm O}$ (or equivalently its density $\rho_{\rm O} = \mu_{\rm O}/\pi R_{\rm O}^2$), and its aspect ratio, $A_{\rm O}$ ($\equiv Z_{\rm O}/R_{\rm O}$, where $Z_{\rm O}$ is its half-length). The gas is only allowed to contract longitudinally, i.e. parallel to the symmetry axis of the filament (the z-axis). Pon et al. (2012) have considered the global dynamics of such filaments analytically. They conclude that short filaments ($A_{\rm O} \leq 5$) collapse along the z-axis more-or-less homologously, on a time-scale $t_{\rm HOM} \sim 0.44\,A_{\rm O}\,(G\rho_{\rm O})^{-1/2}$; in contrast, longer filaments ($A_{\rm O} \geq 5$) undergo end-dominated collapse, i.e. two dense clumps form at the ends of the filament and converge on the

centre sweeping up mass as they go, on a time-scale $t_{\rm END} \sim 0.98\,A_{\rm O}^{1/2}\,(G\rho_{\rm O})^{-1/2}$. Our simulations do not corroborate these predictions. First, for all $A_{\rm O} \geq 2$, the collapse time satisfies a single equation

$$t_{\rm COL} \;\sim\; (0.49 + 0.26A_{\rm O})(G\rho_{\rm O})^{-1/2}\,,$$

which for large $A_{\rm O}$ is much longer than the Pon et al. prediction. Second, for all $A_{\rm O} \geq 2$, the collapse is end-dominated. Third, before being swept up, the gas immediately ahead of an end-clump is actually accelerated outwards by the gravitational attraction of the approaching clump, resulting in a significant ram pressure. For high aspect ratio filaments the end-clumps approach an asymptotic inward speed, due to the fact that they are doing work both accelerating and compressing the gas they sweep up. Pon et al. appear to have neglected the outward acceleration and its consequences.

Accepted by MNRAS

http://arxiv.org/pdf/1502.07552

A Search for Consistent Jet and Disk Rotation Signatures in RY Tau

Deirdre Coffey[1], Catherine Dougados[2,3], Sylvie Cabrit[4,3], Jerome Pety[5,4], Francesca Bacciotti[6]

[1] School of Physics, University College Dublin, Belfield, Dublin 4, Ireland
[2] UMI LFCA Universidad de Chile
[3] I.P.A.G. (UMR 5274), BP 53, F-38041 Grenoble Cédex 9, France
[4] LERMA, Observatoire de Paris, UMR 8112 du CNRS, ENS, UPMC, UCP, 61 Av. de l'Observatoire, F-75014 Paris, France
[5] I.R.A.M., 300 rue de la Piscine, Domaine Universitaire, 38406 Saint Martin d'Hres, France
[6] I.N.A.F., Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Florence, Italy

E-mail contact: deirdre.coffey *at* ucd.ie

We present a radial velocity study of the RY Tau jet-disk system, designed to determine whether a transfer of angular momentum from disk to jet can be observed. Many recent studies report on the rotation of T Tauri disks, and on what may be a signature of T Tauri jet rotation. However, due to observational difficulties, few studies report on both disk and jet within the same system to establish if the senses of rotation match and hence can be interpreted as a transfer of angular momentum. We report a clear signature of Keplerian rotation in the RY Tau disk, based on Plateau de Bure observations. We also report on the transverse radial velocity profile of the RY Tau jet close to the star. We identify two distinct profile shapes: a v-shape which appears near jet shock positions, and a flat profile which appears between shocks. We do not detect a rotation signature above 3σ uncertainty in any of our transverse cuts of the jet. Nevertheless, if the jet is currently in steady-state, the errors themselves provide a valuable upper limit on the jet toroidal velocity of 10 km s^{-1}, implying a launch radius of <0.45 AU. However, possible contamination of jet kinematics, via shocks or precession, prevents any firm constraint on the jet launch point, since most of its angular momentum could be stored in magnetic form rather than in rotation of matter.

Accepted by ApJ

http://arxiv.org/pdf/1502.04481

A tidal encounter caught in the act: modelling a star-disc fly-by in the young RW Aurigae system

Fei Dai[1,2], Stefano Facchini[2], Cathie J. Clarke[2], and Thomas J. Haworth[2]

[1] Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
[2] Institute of Astronomy, Madingley Rd, Cambridge, CB3 0HA, UK

E-mail contact: fd284 *at* mit.edu

RW Aurigae (RW Aur) is a binary star system with a long molecular arm trailing the primary star. Cabrit et al. (2006) noted the resemblance between this extended structure and the tidal arm stripped from the primary star in the simulations of star-disc encounters by Clarke & Pringle (1993). In this paper we use new hydrodynamical models and synthetic observations to fit many of the parameters of RW Aur. Using hydrodynamic models we find that the morphological appearance of RW Aur can be indeed explained by a tidal encounter with the secondary star. We

reproduce all the major morphological and kinematic features of the system. Using radiative transfer calculations, we find that synthetic CO and dust continuum observations of our hydrodynamic models agree well with observations. We reproduce all the main features of the line profiles, from emission fluxes to the optical depth of the different components of the system. The agreement between observations and simulations thus lends strong support to the hypothesis of a tidal encounter scenario. Finally, we propose a possible solution for the origin of the dimming of the primary star observed in 2010/2011 by Rodriguez et al. (2013).

Accepted by MNRAS

http://arxiv.org/pdf/1502.06649

Massive young stellar object W42-MME: The discovery of an infrared jet using VLT/NACO near-infrared images

L. K. Dewangan[1], Y. D. Mayya[1], A. Luna[1] and D. K. Ojha[2]

[1] Instituto Nacional de Astrofsica, Óptica y Electrónica, Luis Enrique Erro # 1, Tonantzintla, Puebla, México C.P. 72840

[2] Department of Astronomy and Astrophysics, Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India

E-mail contact: lokeshd *at* inaoep.mx

We report on the discovery of an infrared jet from a deeply embedded infrared counterpart of 6.7-GHz methanol maser emission (MME) in W42 (i.e. W42-MME). We also investigate that W42-MME drives a parsec-scale H_2 outflow, with detection of bow shock feature at ∼0.52 pc to the north. The inner ∼0.4 pc part of the H_2 outflow has a position angle of ∼18° and the position angle of ∼40° is found farther away on either side of outflow from W42-MME. W42-MME is detected at wavelengths longer than 2.2 μm and is a massive young stellar object, with the estimated stellar mass of 19±4 $M_\odot$. We map the inner circumstellar environment of W42-MME using VLT/NACO adaptive optics K_s and L' observations at resolutions ∼0."2 and ∼0."1, respectively. We discover a collimated jet in the inner 4500 AU using the L' band, which contains prominent Brα line emission. The jet is located inside an envelope/cavity (extent ∼10640 AU) that is tapered at both ends and is oriented along the north-south direction. Such observed morphology of outflow cavity around massive star is scarcely known and is very crucial for understanding the jet-outflow formation process in massive star formation. Along the flow axis, which is parallel to the previously known magnetic field, two blobs are found in both the NACO images at distances of ∼11800 AU, located symmetrically from W42-MME. The observed W42-MME jet-outflow configuration can be used to constrain the jet launching and jet collimation models in massive star formation.

Accepted by The Astrophysical Journal

http://arxiv.org/pdf/1502.05531v1.pdf

Spectral Energy Distributions of Accreting Protoplanets

J.A. Eisner[1,2]

[1] Steward Observatory, The University of Arizona, 933 N. Cherry Ave, Tucson, AZ 85721, USA

[2] Visiting Fellow, JILA, University of Colorado and NIST, Boulder, CO 80309, USA

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

Planets are often invoked as the cause of inferred gaps or inner clearings in transition disks. These putative planets would interact with the remnant circumstellar disk, accreting gas and generating substantial luminosity. Here I explore the expected appearance of accreting protoplanets at a range of evolutionary states. I compare synthetic spectral energy distributions with the handful of claimed detections of substellar-mass companions in transition disks. While observed fluxes of candidate companions are generally compatible with accreting protoplanets, challenges remain in reconciling the extended structure inferred in observed objects with the compact emission expected from protoplanets or circumplanetary disks. I argue that a large fraction of transition disks should harbor bright protoplanets, and that more may be detected as larger telescopes open up additional parameter space.

Accepted by ApJL

http://arxiv.org/pdf/1502.05412

A resolved, au-scale gas disk around the B[e] star HD 50138

L.E. Ellerbroek[1], M. Benisty[2], S. Kraus[3], K. Perraut[2], J. Kluska[2], J.B. LeBouquin[2], M. Borges Fernandes[4], A. Domiciano de Souza[5], K. M. Maaskant[6], L. Kaper[1], F. Tramper[1], D. Mourard[5], I. Tallon-Bosc[7], T. tenBrummelaar[8], M. L. Sitko[9,10], D. K. Lynch[11,12] and R. W. Russel[11]

[1] Anton Pannekoek Institute, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands
[2] Universite Grenoble Alpes, IPAG, F-38000 Grenoble, France; CNRS, IPAG, F-38000 Grenoble, France
[3] School of Physics, University of Exeter, Stocker Road, Exeter EX4 4QL, UK
[4] Observatorio Nacional, Rua General Jose Cristino 77, 20921-400 Sao Cristovao, Rio de Janeiro, Brazil
[5] Laboratoire Lagrange, UMR 7293 UNS-CNRS-OCA, Bd de l'observatoire, CS 34229, 06304 Nice Cedex 4, France
[6] Leiden Observatory, Leiden University, PO Box 9513, 2300 RA Leiden, The Netherlands
[7] Universite de Lyon, 69003 Lyon, France; Universite Lyon 1, Observatoire de Lyon, 9 avenue Charles Andre, 69230 Saint Genis Laval; CNRS, UMR 5574, Centre de Recherche Astrophysique de Lyon; ENS, 69007 Lyon, France
[8] The CHARA Array of Georgia State University, Mount Wilson Observatory, 91023 Mount Wilson CA, USA
[9] Department of Physics, University of Cincinnati, Cincinnati OH 45221, USA
[10] Space Science Institute, 4750 Walnut Street, Boulder, CO 80303, USA
[11] The Aerospace Corporation, Los Angeles, CA 90009, USA
[12] Thule Scientific, Topanga, CA 90290, USA

E-mail contact: lucas.ellerbroek *at* gmail.com

HD 50138 is a B[e] star surrounded by a large amount of circumstellar gas and dust. Its spectrum shows characteristics which may indicate either a pre- or a post-main-sequence system. Mapping the kinematics of the gas in the inner few au of the system contributes to a better understanding of its physical nature. We present the first high spatial and spectral resolution interferometric observations of the Brγ line of HD 50138, obtained with VLTI/AMBER. The line emission originates from a region more compact (up to 3 au) than the continuum-emitting region. Blue- and red-shifted emission originates from the two different hemispheres of an elongated structure perpendicular to the polarization angle. The velocity of the emitting medium decreases radially. An overall offset along the NW direction between the line- and continuum-emitting regions is observed. We compare the data with a geometric model of a thin Keplerian disk and a spherical halo on top of a Gaussian continuum. Most of the data are well reproduced by this model, except for the variability, the global offset and the visibility at the systemic velocity. The evolutionary state of the system is discussed; most diagnostics are ambiguous and may point either to a post-main-sequence or a pre-main-sequence nature.

Accepted by 2015, A&A, 573, 77

http://arxiv.org/pdf/1409.7394

Improved angular momentum evolution model for solar-like stars II. Exploring the mass dependence

Florian Gallet[1,2] and Jérôme Bouvier[1,2]

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

E-mail contact: florian.gallet *at* unige.ch

We developed angular momentum evolution models for 0.5 and 0.8 $M_\odot$ stars. The parametric models include a new wind braking law based on recent numerical simulations of magnetised stellar winds, specific dynamo and mass-loss rate prescriptions, as well as core/envelope decoupling. We compare model predictions to the distributions of rotational periods measured for low mass stars belonging to star forming regions and young open clusters. Furthermore, we explore the mass dependence of model parameters by comparing these new models to the solar-mass models we developed earlier. Rotational evolution models are computed for slow, median, and fast rotators at each stellar mass. The models reproduce reasonably well the rotational behaviour of low-mass stars between 1 Myr and 8-10 Gyr, including pre-main sequence to zero-age main sequence spin up, prompt zero-age main sequence spin down, and early-main sequence convergence of the surface rotation rates. Fast rotators are found to have systematically shorter disk lifetimes than moderate and slow rotators, thus enabling dramatic pre-main sequence spin up. They also have shorter core-envelope coupling timescales, i.e., more uniform internal rotation. As to the mass dependence, lower mass stars

require significantly longer core-envelope coupling timescale than solar-type ones, which results in strong differential rotation developing in the stellar interior on the early main sequence. Lower mass stars also require a weaker braking torque to account for their longer spin down timescale on the early main sequence, while they ultimately converge towards lower rotational velocities than solar-type stars on the longer term due to their reduced moment of inertia. We also find evidence that the mass-dependence of the wind braking efficiency may be related to a change of the magnetic topology in lower mass stars.

Accepted by A&A

http://arxiv.org/pdf/1502.05801

Probing the accretion-ejection connection with VLTI/AMBER: High spectral resolution observations of the Herbig Ae star HD163296

R. Garcia Lopez[1,4], L.V. Tambovtseva[1,2], D. Schertl[1], V.P. Grinin[1,2,3], K.-H Hofmann[1], G. Weigelt[1] and A. Caratti o Garatti[1,4]

[1] Max Planck Institute for Radioastronomy, Auf dem Hgel 69, D-53121 Bonn, Germany

[2] Pulkovo Astronomical Observatory of the Russian Academy of Sciences, Pulkovskoe shosse 65, 196140, St. Petersburg, Russia

[3] The V.V. Sobolev Astronomical Institute of the St. Petersburg University, Petrodvorets, 198904 St. Petersburg, Russia

[4] Dublin Institute for Advanced Studies, 31 Fitzwilliam Place, Dublin 2, Ireland

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

Accretion and ejection are tightly connected and represent the fundamental mechanisms regulating star formation. However, the exact physical processes involved are not yet fully understood. We present high angular and spectral resolution observations of the Brγ emitting region in the Herbig Ae star HD 163296 (MWC 275) in order to probe the origin of this line and constrain the physical processes taking place at sub-AU scales in the circumstellar region. By means of VLTI-AMBER observations at high spectral resolution (R$\sim$12 000), we studied interferometric visibilities, wavelength-differential phases, and closure phases across the Brγ line of HD 163296. To constrain the physical origin of the Brγ line in Herbig Ae stars, all the interferometric observables were compared with the predictions of a line radiative transfer disc wind model. The measured visibilities clearly increase within the Brγ line, indicating that the Brγ emitting region is more compact than the continuum. By fitting a geometric Gaussian model to the continuum-corrected Brγ visibilities, we derived a compact radius of the Brγ emitting region of $\sim$0.07$\pm$0.02 AU (Gaussian half width at half maximum; or a ring-fit radius of $\sim$0.08$\pm$0.02 AU). To interpret the observations, we developed a magneto-centrifugally driven disc wind model. Our best disc wind model is able to reproduce, within the errors, all the interferometric observables and it predicts a launching region with an outer radius of $\sim$0.04 AU. However, the intensity distribution of the entire disc wind emitting region extends up to $\sim$0.16 AU. Our observations, along with a detailed modelling of the Brγ emitting region, suggest that most of the Brγ emission in HD 163296 originates from a disc wind with a launching region that is over five times more compact than previous estimates of the continuum dust rim radius.

Accepted by A&A

http://arxiv.org/pdf/1502.03027

Impacts of pure shocks in the BHR71 bipolar outflow

A. Gusdorf[1], D. Riquelme[2], S. Anderl[3], J. Eislöffel[4], C. Codella[5], A.I. Gómez-Ruiz[2], U.U. Graf[6], L.E. Kristensen[7], S. Leurini[2], B. Parise[8], M.A. Requena-Torres[2], O. Ricken[2], and R. Güsten[2]

[1] LERMA, Observatoire de Paris, École Normale Suprieure, PSL Research University, CNRS, UMR 8112, F-75014, Paris, France; Sorbonne Universités, UPMC Univ. Paris 6, UMR 8112, LERMA, F-75005, Paris, France

[2] Max Planck Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

[3] Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France; CNRS, IPAG, F-38000 Grenoble, France

[4] Thüringer Landessternwarte, Sternwarte 5, 07778, Tautenburg, Germany

[5] INAF, Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125, Firenze, Italy

[6] KOSMA, I. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany

[7] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[8] School of Physics & Astronomy, Cardiff University, Queens Buildings, The parade, Cardiff CF24 3AA, UK

E-mail contact: antoine.gusdorf *at* lra.ens.fr

During the formation of a star, material is ejected along powerful jets that impact the ambient material. This outflow regulates star formation by e.g. inducing turbulence and heating the surrounding gas. Understanding the associated shocks is therefore essential to the study of star formation. We present comparisons of shock models with CO, H_2, and SiO observations in a 'pure' shock position in the BHR71 bipolar outflow. These comparisons provide an insight into the shock and pre-shock characteristics, and allow us to understand the energetic and chemical feedback of star formation on Galactic scales. New CO ($J_{\rm up}$ = 16, 11, 7, 6, 4, 3) observations from the shocked regions with the SOFIA and APEX telescopes are presented and combined with earlier H_2 and SiO data (from the Spitzer and APEX telescopes). The integrated intensities are compared to a grid of models that were obtained from a magneto-hydrodynamical shock code which calculates the dynamical and chemical structure of these regions combined with a radiative transfer module based on the 'large velocity gradient' approximation. The CO emission leads us to update the conclusions of our previous shock analysis: pre-shock densities of 10^4 cm^{-3} and shock velocities around 20–25 km s^{-1} are still constrained, but older ages are inferred (4000 years). We evaluate the contribution of shocks to the excitation of CO around forming stars. The SiO observations are compatible with a scenario where less than 4% of the pre-shock SiO belongs to the grain mantles. We infer outflow parameters: a mass of 1.8×10^{-2} $M_\odot$ was measured in our beam, in which a momentum of 0.4 $M_\odot$ km s^{-1} is dissipated, for an energy of 4.2×10^{43} erg. We analyse the energetics of the outflow species by species. Comparing our results with previous studies highlights their dependence on the method: H_2 observations only are not sufficient to evaluate the mass of outflows.

Accepted by A&A

http://arxiv.org/pdf/1502.00488

A Survey of Irradiated Pillars, Globules, and Jets in the Carina Nebula

Patrick Hartigan[1], Megan Reiter[2], Nathan Smith[2] and John Bally[3]

[1] Physics and Astronomy Dept., Rice University, USA
[2] Dept. of Astronomy, University of Arizona, USA
[3] CASA, University of Colorado Boulder, USA

E-mail contact: hartigan *at* sparky.rice.edu

We present wide-field, deep narrowband H2, Br-gamma, H-alpha, [S II], [O III], and broadband I and K-band images of the Carina star formation region. The new images provide a large-scale overview of all the H2 and Br-gamma emission present in over a square degree centered on this signature star forming complex. By comparing these images with archival HST and Spitzer images we observe how intense UV radiation from O and B stars affects star formation in molecular clouds. We use the images to locate new candidate outflows and identify the principal shock waves and irradiated interfaces within dozens of distinct areas of star-forming activity. Shocked molecular gas in jets traces the parts of the flow that are most shielded from the intense UV radiation. Combining the H2 and optical images gives a more complete view of the jets, which are sometimes only visible in H2. The Carina region hosts several compact young clusters, and the gas within these clusters is affected by radiation from both the cluster stars and the massive stars nearby. The Carina Nebula is ideal for studying the physics of young H II regions and PDR's, as it contains multiple examples of walls and irradiated pillars at various stages of development. Some of the pillars have detached from their host molecular clouds to form proplyds. Fluorescent H2 outlines the interfaces between the ionized and molecular gas, and after removing continuum, we detect spatial offsets between the Br-gamma and H2 emission along the irradiated interfaces. These spatial offsets can be used to test current models of PDRs once synthetic maps of these lines become available.

Accepted by Astronomical Journal

http://sparky.rice.edu/~hartigan/pub/papers/carinah2.pdf
http://arxiv.org/pdf/1502.03798

Properties of the Molecular Cores of Low Luminosity Objects

Tien-Hao Hsieh[1,2], Shih-Ping Lai[1], Arnaud Belloche[2], Friedrich Wyrowski[2], and Chao-Ling Hung[3,4]

[1] Institute of Astronomy, National Tsing Hua University (NTHU), Hsinchu 30013, Taiwan
[2] Max-Planck-Institut für Radioastronomie (MPIfR), Bonn, Germany
[3] Institute for Astronomy, University of Hawaii, USA
[4] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

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

We present a survey toward 16 Low Luminosity Objects (LLOs with an internal luminosity, $L_{\rm int}$, lower than 0.2 $L_\odot$) with N_2H^+ (1–0), N_2H^+ (3–2), N_2D^+ (3–2), HCO^+ (3–2) and HCN (3–2) using the Arizona Radio Observatory Kitt Peak 12m Telescope and Submillimeter Telescope. Our goal is to probe the nature of these faint protostars which are believed to be either very low mass or extremely young protostars. We find that the N_2D^+/N_2H^+ column density ratios of LLOs are similar to those of typical starless cores and Class 0 objects. The N_2D^+/N_2H^+ column density ratios are relatively high (>0.05) for LLOs with kinetic temperatures less than 10 K in our sample. The distribution of N_2H^+ (1–0) line widths spreads between that of starless cores and young Class 0 objects. If we use the line width as a dynamic evolutionary indicator, LLOs are likely young Class 0 protostellar sources. We further use the optically thick tracers, HCO^+ (3–2) and HCN (3–2), to probe the infall signatures of our targets. We derive the asymmetry parameters from both lines and estimate the infall velocities by fitting the HCO^+ (3–2) spectra with two-layer models. As a result, we identify eight infall candidates based on the infall velocities and seven candidates have infall signatures supported by asymmetry parameters from at least one of HCO^+ (3–2) and HCN (3–2).

Accepted by ApJ

http://arxiv.org/pdf/1502.05412

The prevalence of weak magnetic fields in Herbig Ae stars: The case of PDS 2

S. Hubrig[1], T.A. Carroll[1], M. Schöller[2] and I. Ilyin[1]

[1] Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, 14482 Potsdam, Germany
[2] European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching, Germany

E-mail contact: shubrig *at* aip.de

Models of magnetically driven accretion and outflows reproduce many observational properties of T Tauri stars, but the picture is much less clear for the Herbig Ae/Be stars, due to the poor knowledge of their magnetic field strength and topology. The Herbig Ae star PDS 2 was previously included in two magnetic studies based on low-resolution spectropolarimetric observations. Only in one of these studies the presence of a weak mean longitudinal magnetic field was reported. In the present study, for the first time, high-resolution HARPS spectropolarimetric observations of PDS 2 are used to investigate the presence of a magnetic field. A firm detection of a weak longitudinal magnetic field is achieved using the multi-line singular value decomposition method for Stokes profile reconstruction ($\langle B_{\rm z}\rangle = 33 \pm 5$ G). To gain better knowledge of typical magnetic field strengths in late Herbig Be and Herbig Ae stars, we compiled previous magnetic field measurements, revealing that only very few stars have fields stronger than 200 G, and half of the sample possesses fields of about 100 G and less. These results challenge our current understanding of the magnetospheric accretion in intermediate-mass pre-main sequence stars as they indicate that the magnetic fields in Herbig Ae/Be stars are by far weaker than those measured in T Tauri stars.

Accepted by MNRAS

http://arxiv.org/pdf/1502.05498

Discovery of Resolved Debris Disk Around HD 131835

Li-Wei Hung[1], Michael P. Fitzgerald[1], Christine H. Chen[2], Tushar Mittal[3], Paul G. Kalas[4], James R. Graham[4]

[1] Department of Physics and Astronomy, University of California, Los Angeles, CA 90095, USA
[2] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
[3] Department of Earth and Planetary Science, University of California, Berkeley, CA 94720, USA

[4] Department of Astronomy, University of California, Berkeley, CA 94720, USA

E-mail contact: liweih *at* astro.ucla.edu

We report the discovery of the resolved disk around HD 131835 and present the analysis and modeling of its thermal emission. HD 131835 is a ∼15 Myr A2 star in the Scorpius-Centaurus OB association at a distance of $122.7^{+16.2}_{-12.8}$ pc. The extended disk has been detected to ∼1.″5 (200 AU) at 11.7 μm and 18.3 μm with T-ReCS on Gemini South. The disk is inclined at an angle of ∼75° with the position angle of ∼61°. The flux of HD 131835 system is 49.3±7.6 mJy and 84±45 mJy at 11.7 μm and 18.3 μm respectively. A model with three grain populations gives a satisfactory fit to both the spectral energy distribution and the images simultaneously. This best-fit model is composed of a hot continuous power-law disk and two rings. We characterized the grain temperature profile and found that the grains in all three populations are emitting at temperatures higher than blackbodies. In particular, the grains in the continuous disk are unusually warm; even when considering small graphite particles as the composition.

Accepted by ApJ

http://arxiv.org/pdf/1502.02035

SOFIA/EXES Observations of Water Absorption in the Protostar AFGL 2591 at High Spectral Resolution

Nick Indriolo[1,2], D.A. Neufeld[1], C.N. DeWitt[3], M.J. Richter[3], A.C.A. Boogert[4], G.M. Harper[5], D.T. Jaffe[6], K.R. Kulas[7], M.E. McKelvey[8], N. Ryde[9], W. Vacca[4]

[1] Department of Physics and Astronomy, Johns Hopkins University, Baltimore, MD 21218, USA
[2] Current address: Department of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA
[3] Department of Physics, University of California Davis, Davis, CA 95616, USA
[4] USRA, SOFIA, NASA Ames Research Center, MS 232-11, Moffett Field, CA 94035, USA
[5] School of Physics, Trinity College, Dublin 2, Ireland
[6] Department of Astronomy, University of Texas, Austin, TX 78712, USA
[7] Department of Physics, Santa Clara University, Santa Clara, CA 95053, USA
[8] NASA Ames Research Center, Moffett Field, CA 94035, USA
[9] Department of Astronomy and Theoretical Physics, Lund University, Lund, Sweden

E-mail contact: indriolo *at* umich.edu

We present high spectral resolution (∼3 km s^{-1}) observations of the ν_2 ro-vibrational band of H_2O in the 6.086–6.135 μm range toward the massive protostar AFGL 2591 using the Echelon-Cross-Echelle Spectrograph (EXES) on the Stratospheric Observatory for Infrared Astronomy (SOFIA). Ten absorption features are detected in total, with seven caused by transitions in the ν_2 band of H_2O, two by transitions in the first vibrationally excited ν_2 band of H_2O, and one by a transition in the ν_2 band of $H_2{}^{18}O$. Among the detected transitions is the ν_2 $1_{1,1}$–$0_{0,0}$ line which probes the lowest lying rotational level of para-H_2O. The stronger transitions appear to be optically thick, but reach maximum absorption at a depth of about 25%, suggesting that the background source is only partially covered by the absorbing gas, or that the absorption arises within the 6 micron emitting photosphere. Assuming a covering fraction of 25%, the H_2O column density and rotational temperature that best fit the observed absorption lines are $N(H_2O) = (1.3 \pm 0.3) \times 10^{19}$ cm^{-2} and $T = 640 \pm 80$ K.

Accepted by ApJL

http://arxiv.org/pdf/1502.06611

Star Formation Activity in the Long, Filamentary Infrared Dark Cloud G53.2

Hyun-Jeong Kim[1], Bon-Chul Koo[2], Christopher J. Davis[3]

[1] Department of Physics and Astronomy, Seoul National University, Seoul 151-742, Korea
[2] Astrophysics Research Institute, Liverpool John Moores University, Liverpool, L3 5RF, UK

E-mail contact: hjkim *at* astro.snu.ac.kr

We present star formation activity in the infrared dark cloud (IRDC) G53.2, a remarkable IRDC located at Galactic coordinates (l, b) ∼ (53.°2, 0.°0) based on the census of young stellar object (YSO) candidates. IRDC G53.2 was

previously identified as several IRDCs in mid-IR images, but it is in fact a long ($\gtrsim$45 pc) cloud, well consistent with a CO cloud at $v \sim 23$ km s^{-1} (or at $d \sim 1.7$ kpc). We present a point-source catalog of IRDC G53.2 that contains $\sim$370 sources from our photometry of the *Spitzer* MIPS 24 μm data and Galactic Legacy Infrared Mid-Plane Survey Extraordinaire Catalog. The classification of the identified sources based on their spectral index and control field analysis to remove field star contamination reveals that IRDC G53.2 is an active star-forming region with $\sim$300 YSO candidates. We compare the YSO classification based on spectral index, mid-IR colors, and the wavelength range used, which results in consistent classification, except for flat-spectrum objects, with some ambiguity between Class I and II. Comparison of the YSO population in IRDC G53.2 with those of other nearby star-forming clusters indicates that they are similar in age; on the other hand, stronger association with mid-IR stellar sources in IRDC G53.2 compared with other IRDCs indicates that IRDC G53.2 is at a later evolutionary stage among IRDCs. Spatial distribution of the YSO candidates in IRDC G53.2 shows a good correlation with ^{13}CO column density and far-IR emission, and earlier-class objects tend to be more clustered in the regions with higher density.

Accepted by ApJ

http://arxiv.org/pdf/1502.04598

The Deuterium Fractionation Timescale in Dense Cloud Cores: A Parameter Space Exploration

Shuo Kong[1], Paola Caselli[2,3], Jonathan C. Tan[1,4], Valentine Wakelam[5,6] and Olli Sipilä[2]

[1] Dept. of Astronomy, University of Florida, Gainesville, Florida 32611, USA
[2] Max-Planck-Institute for Extraterrestrial Physics (MPE), Giessenbachstr. 1, D-85748 Garching, Germany
[3] School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, UK
[4] Dept. of Physics, University of Florida, Gainesville, Florida 32611, USA
[5] University of Bordeaux, LAB, UMR 5804, 33270, Floirac, France
[6] CNRS, LAB, UMR 5804, 33270, Floirac, France

E-mail contact: skong *at* ufl.edu

The deuterium fraction $[N_2D^+]/[N_2H^+]$, may provide information about the ages of dense, cold gas structures, important to compare with dynamical models of cloud core formation and evolution. Here we introduce a complete chemical network with species containing up to three atoms, with the exception of the Oxygen chemistry, where reactions involving H_3O^+ and its deuterated forms have been added, significantly improving the consistency with comprehensive chemical networks. Deuterium chemistry and spin states of H_2 and H_3^+ isotopologues are included in this primarily gas-phase chemical model. We investigate dependence of deuterium chemistry on model parameters: density (n_H), temperature, cosmic ray ionization rate, and gas-phase depletion factor of heavy elements (f_D). We also explore the effects of time-dependent freeze-out of gas-phase species and dynamical evolution of density at various rates relative to free-fall collapse. For a broad range of model parameters, the timescales to reach large values of $D_{\rm frac}^{\rm N_2H^+} \gtrsim 0.1$, observed in some low- and high-mass starless cores, are relatively long compared to the local free-fall timescale. These conclusions are unaffected by introducing time-dependent freeze-out and considering models with evolving density, unless the initial $f_D \gtrsim 10$. For fiducial model parameters, achieving $D_{\rm frac}^{\rm N_2H^+} \gtrsim 0.1$ requires collapse to be proceeding at rates at least several times slower than that of free-fall collapse, perhaps indicating a dynamically important role for magnetic fields in the support of starless cores and thus the regulation of star formation.

Accepted by ApJ

http://arxiv.org/pdf/1312.0971

Exploring intermediate (5-40AU) scales around AB Aurigae with the Palomar Fiber Nuller

J. Kühn[1], B. Mennesson[1], K. Liewer[1], S. Martin[1], F. Loya[1], R. Millan-gabet[2], and E. Serabyn[1]

[1] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA
[2] NASA Exoplanet Science Institute, California Institute of Technology, Pasadena, CA 91125, USA

E-mail contact: jonas.kuehn *at* a3.epfl.ch

We report on recent K_s-band interferometric observations of the young pre-main-sequence star AB Aurigae obtained with the Palomar Fiber Nuller (PFN). Reaching a contrast of a few 10^{-4} inside a field of view extending from 35 to 275 mas (5–40 AU at AB Aur's distance), the PFN is able to explore angular scales that are intermediate between those accessed by coronagraphic imaging and long baseline interferometry. This intermediate region is of special interest given that many young stellar objects are believed to harbor extended halos at such angular scales. Using destructive interference (nulling) between two sub-apertures of the Palomar 200 inch telescope and rotating the telescope pupil, we measured a resolved circumstellar excess at all probed azimuth angles. The astrophysical null measured over the full rotation is fairly constant, with a mean value of 1.52%, and a slight additional azimuthal modulation of $\pm 0.2\%$. The isotropic astrophysical null is indicative of circumstellar emission dominated by an azimuthally extended source, possibly a halo, or one or more rings of dust, accounting for several percent of the total K_s-band flux. The modest azimuthal variation may be explained by some skewness or anisotropy of the spatially extended source, e.g., an elliptical or spiral geometry, or clumping, but it could also be due to the presence of a point source located at a separation of ~120 mas (17 AU) with $\sim 6 \times 10^{-3}$ of the stellar flux. We combine our results with previous Infrared Optical Telescope Array observations of AB Aur at H band, and demonstrate that a dust ring located at ~30 mas (4.3 AU) represents the best-fitting model to explain both sets of visibilities.We are also able to test a few previously hypothesized models of the incoherent component evident at longer interferometric baselines.

Accepted by ApJ

http://arxiv.org/pdf/1502.03626

Sejong Open Cluster Survey (SOS) - IV. The Young Open Clusters NGC 1624 and NGC 1931

Beomdu Lim[1,5], Hwankyung Sung[2], Michael S. Bessell[3], Jinyoung S. Kim[4], Hyeonoh Hur[2], and Byeong-Gon Park[1]

[1] Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, Yuseong-gu, Daejeon 305-348, Korea

[2] Department of Astronomy and Space Science, Sejong University, 209 Neungdong-ro, Gwangjin-gu, Seoul 143-747, Korea

[3] Research School of Astronomy and Astrophysics, Australian National University, MSO, Cotter Road, Weston, ACT 2611, Australia

[4] Steward Observatory, University of Arizona, 933 N. Cherry Ave. Tucson, AZ 85721-0065, USA

[5] Corresponding author, Korea Research Council of Fundamental Science & Technology Research Fellow

E-mail contact: bdlim1210 *at* kasi.re.kr

Young open clusters located in the outer Galaxy provide us with an opportunity to study star formation activity in a different environment from the solar neighborhood. We present a $UBVI$ and Hα photometric study of the young open clusters NGC 1624 and NGC 1931 that are situated toward the Galactic anticenter. Various photometric diagrams are used to select the members of the clusters and to determine the fundamental parameters. NGC 1624 and NGC 1931 are, on average, reddened by $\langle E(B-V)\rangle = 0.92 \pm 0.05$ and 0.74 ± 0.17 mag, respectively. The properties of the reddening toward NGC 1931 indicate an abnormal reddening law ($R_{V,\mathrm{cl}} = 5.2 \pm 0.3$). Using the zero-age main sequence fitting method we confirm that NGC 1624 is 6.0 ± 0.6 kpc away from the Sun, whereas NGC 1931 is at a distance of 2.3 ± 0.2 kpc. The results from isochrone fitting in the Hertzsprung-Russell diagram indicate the ages of NGC 1624 and NGC 1931 to be less than 4 Myr and 1.5–2.0 Myr, respectively. We derived the initial mass function (IMF) of the clusters. The slope of the IMF ($\Gamma_{\mathrm{NGC\ 1624}} = -2.0 \pm 0.2$ and $\Gamma_{\mathrm{NGC\ 1931}} = -2.0 \pm 0.1$) appears to be steeper than that of the Salpeter/Kroupa IMF. We discuss the implication of the derived IMF based on simple Monte-Carlo simulations and conclude that the property of star formation in the clusters seems not to be far different from that in the solar neighborhood.

Accepted by AJ

http://arxiv.org/pdf/1502.00105

Molecular clouds have power-law probability distribution functions

Marco Lombardi[1,3], Joao Alves[2] and Charles J. Lada[3]

[1] University of Milan, Department of Physics, via Celoria 16, I-20133 Milan, Italy

[2] University of Vienna, Tuerkenschanzstrasse 17, 1180 Vienna, Austria

[3] Harvard-Smithsonian Center for Astrophysics, Mail Stop 72, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: marco.lombardi *at* unimi.it

In this letter we investigate the shape of the probability distribution of column densities (PDF) in molecular clouds. Through the use of low-noise, extinction-calibrated *Herschel*/*Planck* emission data of eight molecular clouds, we demonstrate that, contrary to common belief, the PDFs of molecular clouds are not well described by log-normal functions, but are rather power-laws with exponents close to two, and with breaks between $A_K \simeq 0.1$ and 0.2 mag close to the CO self-shielding limit and not far from the transition between molecular and atomic gas. Additionally, we argue that the intrinsic functional form of the PDF cannot be securely determined below $A_K \simeq 0.1$ mag, limiting our ability to investigate more complex models for the shape of the cloud PDF.

Accepted by Astronomy & Astrophysics Letter

http://arxiv.org/pdf/1502.03859

Shedding light on the formation of the pre-biotic molecule formamide with ASAI

Ana López-Sepulcre[1,2,3], Ali A. Jaber[2,3,4], Edgar Mendoza[5], Bertrand Lefloch[2,3], Cecilia Ceccarelli[2,3], Charlotte Vastel[6,7], Rafael Bachiller[8], José cernicharo[9], Claudio Codella[10], Claudine Kahane[2,3], Mihkel Kama[11] and Mario Tafalla[8]

[1] The University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan
[2] Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France
[3] CNRS, IPAG, F-38000 Grenoble, France
[4] University of AL-Muthana, AL-Muthana, Iraq
[5] Observatório do Valongo, Universidade Federal do Rio de Janeiro - UFRJ, Rio de Janeiro, Brazil
[6] Université de Toulouse, UPS-OMP, IRAP, Toulouse, France
[7] CNRS, IRAP, 9 Av. colonel Roche, BP 44346, 31028 Toulouse Cedex 4, France
[8] IGN Observatorio Astronômico Nacional (IGN), Calle Alfonso XII, 3. 28014 Madrid, Spain
[9] LAM, CAB-CSIC/INTA, Ctra de Torrejón a Ajalvir km 4, 28850 Torrejon de Ardoz, Madrid, Spain
[10] INAF, Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125, Firenze, Italy
[11] Leiden Observatory, P.O. Box 9513, NL-2300 RA, Leiden, The Netherlands

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

Formamide (NH_2CHO) has been proposed as a pre-biotic precursor with a key role in the emergence of life on Earth. While this molecule has been observed in space, most of its detections correspond to high-mass star-forming regions. Motivated by this lack of investigation in the low-mass regime, we searched for formamide, as well as isocyanic acid (HNCO), in 10 low- and intermediate-mass pre-stellar and protostellar objects. The present work is part of the IRAM Large Programme ASAI (Astrochemical Surveys At IRAM), which makes use of unbiased broadband spectral surveys at millimetre wavelengths. We detected HNCO in all the sources and NH_2CHO in five of them. We derived their abundances and analysed them together with those reported in the literature for high-mass sources. For those sources with formamide detection, we found a tight and almost linear correlation between HNCO and NH_2CHO abundances, with their ratio being roughly constant –between 3 and 10– across 6 orders of magnitude in luminosity. This suggests the two species are chemically related. The sources without formamide detection, which are also the coldest and devoid of hot corinos, fall well off the correlation, displaying a much larger amount of HNCO relative to NH_2CHO. Our results suggest that, while HNCO can be formed in the gas phase during the cold stages of star formation, NH_2CHO forms most efficiently on the mantles of dust grains at these temperatures, where it remains frozen until the temperature rises enough to sublimate the icy grain mantles. We propose hydrogenation of HNCO as a likely formation route leading to NH_2CHO.

Accepted by Monthly Notices of the Royal Astronomical Society

http://arxiv.org/pdf/1502.05762

Accretion Phase of Star Formation in Clouds with Different Metallicities

Masahiro N. Machida[1] and Teppei Nakamura[1]

[1] Department of Earth and Planetary Sciences, Faculty of Sciences, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka, Japan

E-mail contact: machida.masahiro.018 *at* m.kyushu-u.ac.jp

The main accretion phase of star formation is investigated in clouds with different metallicities in the range of $0 \leq Z \leq Z_\odot$, resolving the protostellar radius. Starting from a near-equilibrium prestellar cloud, we calculate the cloud evolution up to ∼100 yr after the first protostar formation. The star formation process considerably differs between clouds with lower ($Z \leq 10^{-4} Z_\odot$) and higher ($Z > 10^{-4} Z_\odot$) metallicities. Fragmentation frequently occurs and many protostars appear without forming a stable circumstellar disc in lower-metallicity clouds. In these clouds, although protostars mutually interact and some are ejected from the cloud centre, many remain as a small stellar cluster. In contrast, higher-metallicity clouds produce a single protostar surrounded by a nearly stable rotation-supported disc. In these clouds, although fragmentation occasionally occurs in the disc, the fragments migrate inwards and finally fall onto the central protostar. The difference in cloud evolution is due to different thermal evolutions and mass accretion rates. The thermal evolution of the cloud determines the emergence and lifetime of the first core. The first core develops prior to the protostar formation in higher-metallicity clouds, whereas no (obvious) first core appears in lower-metallicity clouds. The first core evolves into a circumstellar disc with a spiral pattern, which effectively transfers the angular momentum outwards and suppresses frequent fragmentation. In lower-metallicity clouds, the higher mass accretion rate increases the disc surface density within a very short time, rendering the disc unstable to self-gravity and inducing vigorous fragmentation.

Accepted by MNRAS

http://arxiv.org/pdf/1502.01808

Searching for signatures of planet formation in stars with circumstellar debris discs

J. Maldonado[1], C. Eiroa[2], E. Villaver[2], B. Montesinos[3], and A. Mora[4]

[1] INAF - Osservatorio Astronomico di Palermo, Piazza Parlamento 1, 90134 Palermo, Italy
[2] Universidad Autnoma de Madrid, Dpto. Fsica Terica, Mdulo 15, Facultad de Ciencias, Campus de Cantoblanco, 28049 Madrid, Spain
[3] Department of Astrophysics, Centro de Astrobiología (CAB, CSIC-INTA), ESAC Campus, PO Box 78, 28691 Villanueva de la Cañada, Madrid, Spain
[4] ESA-ESAC Gaia SOC, PO Box 78, 28691 Villanueva de la Cañada, Madrid, Spain

E-mail contact: jmaldonado *at* astropa.inaf.it

Tentative correlations between the presence of dusty debris discs and low-mass planets have been presented. In parallel, detailed chemical abundance studies have reported different trends between samples of planet and non-planet hosts. We determine in a homogeneous way the metallicity, and abundances of a sample of 251 stars including stars with known debris discs, with debris discs and planets, and only with planets. Stars with debris discs and planets have the same [Fe/H] behaviour as stars hosting planets, and they also show a similar <[X/Fe]>–T_c trend. Different behaviour in the <[X/Fe]>–T_c trend is found between the samples of stars without planets and the samples of planet hosts. In particular, when considering only refractory elements, negative slopes are shown in cool giant planet hosts, whilst positive ones are shown in stars hosting low-mass planets. Stars hosting exclusively close-in giant planets show higher metallicities and positive<[X/Fe]>–T_c slope. A search for correlations between the <[X/Fe]>–T_c slopes and the stellar properties reveals a moderate but significant correlation with the stellar radius and as well as a weak correlation with the stellar age. The fact that stars with debris discs and stars with low-mass planets do not show neither metal enhancement nor a different <[X/Fe]>–T_c trend might indicate a correlation between the presence of debris discs and the presence of low-mass planets. We extend results from previous works which reported differences in the <[X/Fe]>–T_c trends between planet hosts and non hosts. However, these differences tend to be present only when the star hosts a cool distant planet and not in stars hosting exclusively low-mass planets.

Accepted by A&A

http://arxiv.org/pdf/1502.07100

On the gap-opening criterion of migrating planets in protoplanetary disks

Matej Malik[1,2], Farzana Meru[1,3], Lucio Mayer[4] and Michael R. Meyer[1]

[1] ETH Zürich, Institute for Astronomy, Wolfgang-Pauli-Strasse 27, CH-8093, Zürich, Switzerland
[2] University of Bern, Center for Space and Habitability, Hochschulstrasse 5, CH-3012, Bern, Switzerland
[3] University of Cambridge, Institute of Astronomy, Madingley Road, Cambridge, CB3 0HA, United Kingdom

[4] University of Zürich, Institute for Computational Science, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland

E-mail contact: matej.malik *at* csh.unibe.ch

We perform two-dimensional hydrodynamical simulations to quantitatively explore the torque balance criterion for gap-opening (as formulated by Crida et al. 2006) in a variety of disks when considering a migrating planet. We find that even when the criterion is satisfied, there are instances when planets still do not open gaps. We stress that gap-opening is not only dependent on whether a planet has the ability to open a gap, but whether it can do so *quickly* enough. This can be expressed as an additional condition on the gap-opening timescale, $t_{\rm gap}$, versus the crossing time, $t_{\rm cross}$, i.e. the time it takes the planet to cross the region which it is carving out. While this point has been briefly made in the previous literature, our results quantify it for a range of protoplanetary disk properties and planetary masses, demonstrating how crucial it is for gap-opening. This additional condition has important implications for the survival of planets formed by core accretion in low mass disks as well as giant planets or brown dwarfs formed by gravitational instability in massive disks. It is particularly important for planets with *intermediate* masses susceptible to Type III-like migration. For some observed transition disks or disks with gaps, we expect that estimates on the potential planet masses based on the torque balance gap-opening criterion alone may not be sufficient. With consideration of this additional timescale criterion theoretical studies may find a reduced planet survivability or that planets may migrate further inwards before opening a gap.

Accepted by ApJ

http://arxiv.org/pdf/1502.06597

An origin of arc structures deeply embedded in dense molecular cloud cores

Tomoaki Matsumoto[1], Toshikazu Onishi[2], Kazuki Tokuda[2] and Shu-ichiro Inutsuka[3]

[1] Faculty of Humanity and Environment, Hosei University, Fujimi, Chiyoda-ku, Tokyo 102-8160, Japan

[2] Department of Physical Science, Graduate School of Science, Osaka Prefecture University, 1-1 Gakuen-cho, Naka-ku, Sakai, Osaka 599-8531, Japan

[3] Department of Physics, Nagoya University, Chikusa-ku, Nagoya 464-8602, Japan

E-mail contact: matsu *at* hosei.ac.jp

We investigated the formation of arc-like structures in the infalling envelope around protostars, motivated by the recent ALMA observations of the high-density molecular cloud core, MC27/L1527F. We performed self-gravitational hydrodynamical numerical simulations with an adaptive mesh refinement code. A filamentary cloud with a 0.1 pc width fragments into cloud cores because of perturbations due to weak turbulence. The cloud core undergoes gravitational collapse to form multiple protostars, and gravitational torque from the orbiting protostars produces arc structures extending up to a 1000 AU scale. As well as on a spatial extent, the velocity ranges of the arc structures, $\sim 0.5\,{\rm km\,s^{-1}}$, are in agreement with the ALMA observations. We also found that circumstellar disks are often misaligned in triple system. The misalignment is caused by the tidal interaction between the protostars when they undergo close encounters because of a highly eccentric orbit of the tight binary pair.

Accepted by MNRAS

http://arxiv.org/pdf/1502.03611

CSI 2264: Probing the inner disks of AA Tau-like systems in NGC 2264

P. T. McGinnis[1], S. H. P. Alencar[1], M. M. Guimarães[2], A. P. Sousa[1], J. Stauffer[3], J. Bouvier[4,5], L. Rebull[3], N. N. J. Fonseca[1,4], L. Venuti[4], L. Hillenbrand[6], A. M. Cody[3], P. S. Teixeira[7], S. Aigrain[8], F. Favata[9], G. Fűrész[10], F. J. Vrba[11], E. Flaccomio[12], N. Turner[13], J. F. Gameiro[14], C. Dougados[4], W. Herbst[15], M. Morales-Calderón[16] and G. Micela[12]

[1] Departamento de Física - ICEx - UFMG, Av. Antônio Carlos, 6627, 30270-901 Belo Horizonte, MG, Brazil

[2] Departamento de Física e Matemática - UFSJ - Rodovia MG 443, KM 7, 36420-000, Ouro Branco, MG, Brazil

[3] *Spitzer* Science Center, California Institute of Technology, Pasadena, CA 91125, USA

[4] Univ. Grenoble Alpes, IPAG, F-38000 Grenoble, France

[5] CNRS, IPAG, F-38000 Grenoble, France

[6] Astronomy Department, California Institute of Technology, Pasadena, CA 91125, USA

[7] University of Vienna, Department of Astrophysics, Türkenschanzstr. 17, 1180 Vienna, Austria
[8] Department of Astrophysics, Denys Wilkinson Building, University of Oxford, Oxford OX1 3RH, UK
[9] European Space Agency, 8-10 rue Mario Nikis, F-75738 Paris, Cedex 15, France
[10] MIT Kavli Institute for Astrophysics and Space Research, 77 Mass Ave 37-582f, Cambridge, MA 02139
[11] U.S. Naval Observatory, Flagstaff Station, 10391 West Naval Observatory Road, Flagstaff, AZ 86001, USA
[12] INAF - Observatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134, Palermo, Italy
[13] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
[14] Instituto de Astrofísica e Ciências Espaciais and Faculdade de Ciências, Universidade do Porto, Rua das Estrelas, PT4150-762 Porto, Portugal
[15] Astronomy Department, Wesleyan University, Middletown, CT 06459, USA
[16] Centro de Astrobiología, Departamento de Astrofísica, INTA-CSIC, PO BOX 78, E-28691, ESAC Campus, Villanueva de la Cañada, Madrid, Spain

E-mail contact: pauline *at* fisica.ufmg.br

Context. The classical T Tauri star (CTTS) AA Tau has presented photometric variability that was attributed to an inner disk warp, caused by the interaction between the inner disk and an inclined magnetosphere. Previous studies of the young cluster NGC 2264 have shown that similar photometric behavior is common among CTTS.
Aims. The goal of this work is to investigate the main causes of the observed photometric variability of CTTS in NGC 2264 that present AA Tau-like light curves, and verify if an inner disk warp could be responsible for their observed variability.
Methods. In order to understand the mechanism causing these stars' photometric behavior, we investigate veiling variability in their spectra and u-r color variations and estimate parameters of the inner disk warp using an occultation model proposed for AA Tau. We also compare infrared *Spitzer* IRAC and optical CoRoT light curves to analyze the dust responsible for the occultations.
Results. AA Tau-like variability proved to be transient on a timescale of a few years. We ascribe this variability to stable accretion regimes and aperiodic variability to unstable accretion regimes and show that a transition, and even coexistence, between the two is common. We find evidence of hot spots associated with occultations, indicating that the occulting structures could be located at the base of accretion columns. We find average values of warp maximum height of 0.23 times its radial location, consistent with AA Tau, with variations of on average 11% between rotation cycles. We also show that extinction laws in the inner disk indicate the presence of grains larger than interstellar grains.
Conclusions. The inner disk warp scenario is consistent with observations for all but one star with AA Tau-like variability in our sample. AA Tau-like systems are fairly common, comprising 14% of CTTS observed in NGC 2264, though this number increases to 35% among systems of mass $0.7M_\odot < M < 2.0M_\odot$. Assuming random inclinations, we estimate that nearly all systems in this mass range likely possess an inner disk warp. We attribute this to a possible change in magnetic field configurations among stars of lower mass.

Accepted by A&A

http://arxiv.org/pdf/1502.07692

Photometric study of HD 155555C in the β Pictoris Association

Sergio Messina[1], Mervyn Millward[2], David H. Bradstreet[3]

[1] INAF- Catania Astrophysical Observatory, via S.Sofia, 78 I-95123 Catania, Italy
[2] York Creek Observatory, Georgetown, Tasmania
[3] Eastern University, St. Davids, PA, USA

E-mail contact: sergio.messina *at* oact.inaf.it

We are carrying out a series of photometric monitoring to measure the rotation periods of members in the young β Pictoris Association, as part of the RACE-OC project (Rotation and ACtivity Evolution in Open Clusters). In this paper, we present the results for HD 155555C which is believed to be physically associated to the spectroscopic binary V824 Ara (HD155555) and thus constituting a triple system. We collected B, V, and R-band photometric data timeseries and discovered from periodogram analysis the rotation period $P = 4.43$ d. Combined with stellar radius and projected rotational velocity, we find this star almost equator-on with an inclination $i \approx 90°$. The rotational properties of HD155555C fit well into the period distribution of other β Pic members, giving further support to the suggested

membership to the association and to its physical association to V824 Ara. A comparison with Pre-Main-Sequence isochrones from various models allows us to estimate an age of 20±15 Myr for this triple system.

Accepted by New Astronomy

http://arxiv.org/pdf/1502.02395

Does the presence of planets affect the frequency and properties of extrasolar Kuiper Belts? Results from the Herschel DEBRIS and DUNES surveys

A. Moro-Martín[1,2], J. P. Marshall[3,4,5], G. Kennedy[6], B. Sibthorpe[7], B.C. Matthews[8,9], C. Eiroa[5], M.C. Wyatt[6], J.-F. Lestrade[10], J. Maldonado[11], D. Rodriguez[12], J.S. Greaves[13], B. Montesinos[14], A. Mora[15], M. Booth[16], G. G. Duchêne[17,18,19], D. Wilner[20], J. Horner[21,4]

[1] Space Telescope Science Institute, 3700 San Martin Drive Baltimore, MD 21218, USA
[2] Center for Astrophysical Sciences, Johns Hopkins University, Baltimore MD 21218, USA
[3] School of Physics, University of New South Wales, Sydney, NSW 2052, Australia
[4] Australian Centre for Astrobiology, University of New South Wales, Sydney, NSW 2052, Australia
[5] Departamento de Física Teórica, Universidad Autónoma de Madrid, Cantoblanco, 28049, Madrid, Spain
[6] Institute of Astronomy (IoA), University of Cambridge, Madingley Rd., Cambridge, CB3 0HA, UK
[7] SRON Netherlands Institute for Space Research, NL-9747 AD, Groningen, Netherlands
[8] Herzberg Astronomy and Astrophysics, National Research Council of Canada, 5071 West Saanich Road, Victoria, BC V9E 2E7, Canada
[9] Department of Physics and Astronomy, University of Victoria, Finnerty Road, Victoria, BC, V8W 3P6, Canada
[10] Observatoire de Paris, CNRS, 61 Av. de lObservatoire, F-75014, Paris, France
[11] INAF - Osservatorio Astronomico di Palermo, Piazza Parlamento 1, I-90134 Palermo, Italy
[12] Universidad de Chile, Camino el Observatorio 1515, Las Condes, Santiago, Chile
[13] SUPA, School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews KY16 9SS, UK
[14] Centro de Astrobiología, CSIC-INTA, ESAC Campus, P.O. Box 78, 28691 Villanueva de la Cañada, Madrid, Spain
[15] ESA-ESAC Gaia SOC. P.O. Box 78 28691 Villanueva de la Cañada, Madrid, Spain
[16] Instituto de Astrofísica, Pontíficia Universidad Católica de Chile, Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile
[17] Astronomy Department, University of California, Berkeley, CA 94720, USA
[18] Universite Grenoble Alpes, IPAG, F-38000 Grenoble, France
[19] CNRS, IPAG, F-38000 Grenoble, France
[20] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
[21] Computational Engineering and Science Research Centre, University of Southern Queensland, West Street, Toowoomba Qld 4350, Australia

E-mail contact: amaya *at* stsci.edu

The study of the planet-debris disk connection can shed light on the formation and evolution of planetary systems and may help "predict" the presence of planets around stars with certain disk characteristics. In preliminary analyses of subsamples of the *Herschel DEBRIS* and *DUNES* surveys, Wyatt et al. (2012) and Marshall et al. (2014) identified a tentative correlation between debris and the presence of low-mass planets. Here we use the cleanest possible sample out of these *Herschel* surveys to assess the presence of such a correlation, discarding stars without known ages, with ages < 1 Gyr and with binary companions <100 AU to rule out possible correlations due to effects other than planet presence. In our resulting subsample of 204 FGK stars, we do not find evidence that debris disks are more common or more dusty around stars harboring high-mass or low-mass planets compared to a control sample without identified planets. There is no evidence either that the characteristic dust temperature of the debris disks around planet-bearing stars is any different from that in debris disks without identified planets, nor that debris disks are more or less common (or more or less dusty) around stars harboring multiple planets compared to single-planet systems. Diverse dynamical histories may account for the lack of correlations. The data show a correlation between the presence of high-mass planets and stellar metallicity, but no correlation between the presence of low-mass planets or debris and stellar metallicity. Comparing the observed cumulative distribution of fractional luminosity to those expected from a Gaussian distribution in logarithmic scale, we find that a distribution centered on the Solar system's value fits the data well, while one centered at 10 times this value can be rejected. This is of interest in the context of future terrestrial

planet detection and characterization because it indicates that there are good prospects for finding a large number of debris disk systems (i.e. with evidence of harboring planetesimals, the building blocks of planets) with exozodiacal emission low enough to be appropriate targets for an *ATLAST*-type mission to search for biosignatures.

Accepted by Astrophysical Journal

http://arxiv.org/pdf/1501.03813

Accelerating a water maser face-on jet from a high mass young stellar object

Kazuhito Motogi[1], Kazuo Sorai[2], Mareki Honma[3,4], Tomoya Hirota[3,4], Kazuya Hachisuka[1], Kotaro Niinuma[1,5], Koichiro Sugiyama[6], Yoshinori Yonekura[6], and Kenta Fujisawa[1,5]

[1] The Research Institute of Time Studies, Yamaguchi University, Yoshida 1677-1, Yamaguchi-city, Yamaguchi 753-8511, Japan

[2] Department of Physics / Department of Cosmosciences, Hokkaido University, Kita 10, Nishi 8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan

[3] Mizusawa VLBI Observatory, NAOJ, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

[4] Department of Astronomical Science, Graduate University for Advanced Studies (SOKENDAI), 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

[5] Department of Physics, Faculty of Science, Yamaguchi University, Yoshida 1677-1, Yamaguchi-city, Yamaguchi 753-8512, Japan

[6] Center for Astronomy, Ibaraki University, 2-1-1 Bunkyo, Mito, Ibaraki 310-8512, Japan

E-mail contact: motogi *at* yamguchi-u.ac.jp

We report on a long-term single-dish and VLBI monitoring for intermittent flare activities of a Dominant Blue-Shifted H_2O Maser (DBSM) associated with a southern high mass young stellar object, G353.273+0.641. Bi-weekly single-dish monitoring using Hokkaido University Tomakomai 11-m radio telescope has shown that a systematic acceleration continues over four years beyond a lifetime of individual maser features. This fact suggests that the H_2O maser traces a region where molecular gas is steadily accelerated. There were five maser flares during five-years monitoring, and maser distributions in four of them were densely monitored by the VLBI Exploration of Radio Astrometry (VERA). The overall distribution of the maser features suggests the presence of a bipolar jet, with the 3D kinematics indicating that it is almost face-on (inclination angle of $\sim 8°$–$17°$ from the line-of-sight). Most of maser features were recurrently excited within a region of 100×100 AU^2 around the radio continuum peak, while their spatial distributions significantly varied between each flare. This confirms that episodic propagations of outflow shocks recurrently invoke intermittent flare activities. We also measured annual parallax, deriving the source distance of $1.70^{+0.19}_{-0.16}$ kpc that is consistent with the commonly-used photometric distance.

Accepted by PASJ

http://arxiv.org/pdf/1502.00376

Physical and chemical differentiation of the luminous star-forming region W49A - Results from the JCMT Spectral Legacy Survey

Z. Nagy[1,2], F. F. S. van der Tak[2], G. A. Fuller[3] and R. Plume[4]

[1] Department of Physics and Astronomy, University of Toledo; I. Physikalisches Institut, University of Cologne

[2] Kapteyn Astronomical Institute, University of Groningen; SRON Netherlands Institute for Space Research

[3] Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, University of Manchester, UK

[4] Department of Physics and Astronomy, University of Calgary, Canada

E-mail contact: zsofia.nagy.astro *at* gmail.com

The massive and luminous star-forming region W49A is a well-known Galactic candidate to probe the physical conditions and chemistry similar to those expected in external starburst galaxies.
We aim to probe the physical and chemical structure of W49A on a spatial scale of $\sim$0.8 pc based on the JCMT Spectral Legacy Survey, which covers the frequency range between 330 and 373 GHz.
The wide 2×2 arcminutes field and the high spectral resolution of the HARP instrument on JCMT provides information on the spatial structure and kinematics of the cloud traced by the observed molecular lines. For species

where multiple transitions are available, we estimate excitation temperatures and column densities using a population diagram method that takes beam dilution and optical depth corrections into account.
We detected 255 transitions corresponding to 60 species in the 330-373 GHz range at the center position of W49A. Excitation conditions can be probed for 16 molecules, including the complex organic molecules CH_3CCH, CH_3CN, and CH_3OH. The chemical composition suggests the importance of shock, photon-dominated region (PDR), and hot core chemistry. Many molecular lines show a significant spatial extent across the maps including CO and its isotopologues, high density tracers (e.g., HCN, HNC, CS, HCO^+), and tracers of UV irradiation (e.g., CN and C_2H). The spatially extended species reveal a complex velocity-structure of W49A with possible infall and outflow motions. Large variations are seen between the subregions with mostly blue-shifted emission toward the eastern tail, mostly red-shifted emission toward the northern clump, and emission peaking around the expected source velocity toward the southwest clump.
A comparison of column density ratios of characteristic species observed toward W49A to Galactic PDRs suggests that while the chemistry toward the W49A center is driven by a combination of UV irradiation and shocks, UV irradiation dominates for the northern clump, eastern tail, and southwest clump regions. A comparison to a starburst galaxy and an AGN suggests similar C_2H, CN, and H_2CO abundances (with respect to the dense gas tracer ^{34}CS) between the ∼0.8 pc scale probed for W49A and the >1 kpc regions in external galaxies with global star formation.

Accepted by A&A

http://arxiv.org/pdf/1502.03187

Deep near-infrared adaptive-optics observations of a young embedded cluster at the edge of the RCW 41 HII region

B. Neichel[1], M. R. Samal[1], H. Plana[2], A. Zavagno[1], A. Bernard[1,3] and T. Fusco[1,3]

[1] Aix Marseille Université, CNRS, LAM (Laboratoire d'Astrophysique de Marseille) UMR 7326, 13388, Marseille, France

[2] Laboratorio de Astrofísica Teórica e Observacional, Universidade Estadual de Santa Cruz, Rodovia Jorge Amado km16 45662-900 Ilhéus BA - Brazil

[3] ONERA (Office National dEtudes et de Recherches Arospatiales),B.P.72, F-92322 Chatillon, France

E-mail contact: benoit.neichel *at* lam.fr

We investigate the star formation activity in a young star forming cluster embedded at the edge of the RCW 41 H II region. As a complementary goal, we aim to demonstrate the gain provided by wide-field adaptive optics (WFAO) instruments to study young clusters. We used deep, JHK_s images from the newly commissioned Gemini-GeMS/GSAOI instrument, complemented with *Spitzer* IRAC observations, in order to study the photometric properties of the young stellar cluster. GeMS is a WFAO instrument that delivers almost diffraction-limited images over a field of ∼2 arcminute across. The exquisite angular resolution allows us to reach a limiting magnitude of $J \sim 22$ for 98% completeness. The combination of the IRAC photometry with our JHK_s catalog is used to build color-color diagrams, and select young stellar object (YSO) candidates. The JHK_s photometry is also used in conjunction with pre-main sequence evolutionary models to infer masses and ages. The K-band luminosity function is derived, and then used to build the initial mass function (IMF) of the cluster. We detect the presence of 80 YSO candidates. Those YSOs are used to infer the cluster age, which is found to be in the range 1 to 5 Myr. More precisely, we find that 1/3 of the YSOs are in a range between 3 to 5 Myr, while 2/3 of the YSO are $\leq$ 3 Myr. When looking at the spatial distribution of these two populations, we find evidence of a potential age gradient across the field that suggests sequential star formation. We construct the IMF and show that we can sample the mass distribution well into the brown dwarf regime (down to $\sim 0.01\ M_\odot$). The logarithmic mass function rises to peak at $\sim 0.3\ M_\odot$, before turning over and declining into the brown dwarf regime. The total cluster mass derived is estimated to be $78 \pm 18\ M_\odot$, while the ratio derived of brown dwarfs to star is 18 ± 5 %. When comparing it with other young clusters, we find that the IMF shape of the young cluster embedded within RCW 41 is consistent with those of Trapezium, IC 348, or Chamaeleon I, except for the IMF peak, which happens to be at higher mass. This characteristic is also seen in clusters like NGC 6611 or even Taurus. These results suggest that the medium-to-low mass end of the IMF possibly depends on environment.

Accepted by A&A

http://arxiv.org/pdf/1502.02102

On the effects of solenoidal and compressive turbulence in prestellar cores

O. Lomax[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, Ludwig-Maximilians-University Munich, Scheinerstr.1, D-81679 Munich, Germany
[3] Excellence Cluster Universe, Boltzmannstr. 2, D-85748 Garching, Germany

E-mail contact:

We present the results of an ensemble of SPH simulations that follow the evolution of prestellar cores for 0.2 Myr. All the cores have the same mass, and start with the same radius, density profile, thermal and turbulent energy. Our purpose is to explore the consequences of varying the fraction of turbulent energy, $\delta_{\rm SOL}$, that is solenoidal, as opposed to compressive; specifically we consider $\delta_{\rm SOL} = 1$, 2/3, 1/3, 1/9 and 0. For each value of $\delta_{\rm SOL}$, we follow ten different realisations of the turbulent velocity field, in order also to have a measure of the stochastic variance blurring any systematic trends. With low $\delta_{\rm SOL}(<1/3)$ filament fragmentation dominates and delivers relatively high mass stars. Conversely, with high values of $\delta_{\rm SOL}(>1/3)$ disc fragmentation dominates and delivers relatively low mass stars. There are no discernible systematic trends in the multiplicity statistics obtained with different $\delta_{\rm SOL}$.

Accepted by MNRAS

http://arxiv.org/pdf/1502.04009

The JCMT Gould Belt Survey: First results from the SCUBA-2 observations of the Ophiuchus molecular cloud and a virial analysis of its prestellar core population

K. Pattle[1], D. Ward-Thompson[1], J. M. Kirk[1], G. J. White[2,3], E. Drabek-Maunder[4], J. Buckle[5,6], S.F. Beaulieu[7], D.S. Berry[8], H. Broekhoven-Fiene[9], M.J. Currie[8], M. Fich[7], J. Hatchell[10], H. Kirk[11], T. Jenness[8,12], D. Johnstone[8,11,9], J.C. Mottram[13], D. Nutter[14], J.E. Pineda[15,16,17], C. Quinn[14], C. Salji[5,6], S. Tisi[7], S. Walker-Smith[5,6], J. Di Francesco[11,9], M.R. Hogerheijde[13], Ph. André[18], P. Bastien[19], D. Bresnahan[1], H. Butner[20], M. Chen[9], A. Chrysostomou[21], S. Coude[19], C.J. Davis[22], A. Duarte-Cabral[10], J. Fiege[23], P. Friberg[8], R. Friesen[24], G.A. Fuller[16], S. Graves[5,6], J. Greaves[25], J. Gregson[2,3], M. J. Griffin[14], W. Holland[26,27], G. Joncas[28], L.B.G. Knee[11], V. Könyves[18,29], S. Mairs[9], K. Marsh[14], B.C. Matthews[11,9], G. Moriarty-Schieven[11], J. Rawlings[30], J. Richer[5,6], D. Robertson[31], E. Rosolowsky[32], D. Rumble[10], S. Sadavoy[33], L. Spinoglio[34], H. Thomas[8], N. Tothill[35], S. Viti[30], J. Wouterloot[8], J. Yates[30] and M. Zhu[36]

[1] Jeremiah Horrocks Institute, University of Central Lancashire, Preston, Lancashire, PR1 2HE, UK
[2] Department of Physical Sciences, The Open University, Milton Keynes MK7 6AA, UK
[3] The Rutherford Appleton Laboratory, Chilton, Didcot, OX11 0NL, UK
[4] Imperial College London, Blackett Laboratory, Prince Consort Rd, London SW7 2BB, UK
[5] Astrophysics Group, Cavendish Laboratory, J J Thomson Avenue, Cambridge, CB3 0HE
[6] Kavli Institute for Cosmology, Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK
[7] Department of Physics and Astronomy, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada
[8] Joint Astronomy Centre, 660 N. A'ohōkū Place, University Park, Hilo, Hawaii 96720, USA
[9] Department of Physics and Astronomy, University of Victoria, Victoria, BC, V8P 1A1, Canada
[10] Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK
[11] NRC Herzberg Astronomy and Astrophysics, 5071 West Saanich Rd, Victoria, BC, V9E 2E7, Canada
[12] Department of Astronomy, Cornell University, Ithaca, NY 14853, USA
[13] Leiden Observatory, Leiden University, PO Box 9513, 2300 RA Leiden, The Netherlands
[14] School of Physics and Astronomy, Cardiff University, The Parade, Cardiff, CF24 3AA, UK
[15] European Southern Observatory (ESO), Garching, Germany
[16] Jodrell Bank Centre for Astrophysics, Alan Turing Building, School of Physics and Astronomy, University of Manchester, Oxford Road, Manchester, M13 9PL, UK
[17] Institute for Astronomy, ETH Zurich, Wolfgang-Pauli-Strasse 27, CH-8093 Zurich, Switzerland
[18] Laboratoire AIM CEA/DSM-CNRS-Université Paris Diderot, IRFU/Service d'Astrophysique, CEA Saclay, F-91191 Gif-sur-Yvette, France
[19] Université de Montréal, Centre de Recherche en Astrophysique du Québec et département de physique, C.P. 6128,

succ. centre-ville, Montréal, QC, H3C 3J7, Canada
[20] James Madison University, Harrisonburg, Virginia 22807, USA
[21] School of Physics, Astronomy & Mathematics, University of Hertfordshire, College Lane, Hatfield, Herts, AL10 9AB, UK
[22] Astrophysics Research Institute, Liverpool John Moores University, Egerton Warf, Birkenhead, CH41 1LD, UK
[23] Department of Physics & Astronomy, University of Manitoba, Winnipeg, Manitoba, R3T 2N2 Canada
[24] Dunlap Institute for Astronomy & Astrophysics, University of Toronto, 50 St. George St., Toronto ON M5S 3H4 Canada
[25] Physics & Astronomy, University of St Andrews, North Haugh, St Andrews, Fife KY16 9SS, UK
[26] UK Astronomy Technology Centre, Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK
[27] Institute for Astronomy, Royal Observatory, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, UK
[28] Centre de recherche en astrophysique du Québec et Département de physique, de génie physique et d'optique, Université Laval, 1045 avenue de la médecine, Québec, G1V 0A6, Canada
[29] Institut d'Astrophysique Spatiale, CNRS/Université Paris-Sud 11, F-91405 Orsay, France
[30] Department of Physics and Astronomy, UCL, Gower St, London, WC1E 6BT, UK
[31] Department of Physics and Astronomy, McMaster University, Hamilton, ON, L8S 4M1, Canada
[32] Department of Physics, University of Alberta, Edmonton, AB T6G 2E1, Canada
[33] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany
[34] IFSI - INAF, via Fosso del Cavaliere 100, 00133 Roma, Italy
[35] University of Western Sydney, Locked Bag 1797, Penrith NSW 2751, Australia
[36] National Astronomical Observatory of China, 20A Datun Road, Chaoyang District, Beijing 100012, China

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

In this paper we present the first observations of the Ophiuchus molecular cloud performed as part of the James Clerk Maxwell Telescope (JCMT) Gould Belt Survey (GBS) with the SCUBA-2 instrument. We demonstrate methods for combining these data with previous HARP CO, Herschel, and IRAM N_2H^+ observations in order to accurately quantify the properties of the SCUBA-2 sources in Ophiuchus. We produce a catalogue of all of the sources found by SCUBA-2. We separate these into protostars and starless cores. We list all of the starless cores and perform a full virial analysis, including external pressure. This is the first time that external pressure has been included in this level of detail. We find that the majority of our cores are either bound or virialised. Gravitational energy and external pressure are on average of a similar order of magnitude, but with some variation from region to region. We find that cores in the Oph A region are gravitationally bound prestellar cores, while cores in the Oph C and E regions are pressure-confined. We determine that N_2H^+ is a good tracer of the bound material of prestellar cores, although we find some evidence for N_2H^+ freeze-out at the very highest core densities. We find that non-thermal linewidths decrease substantially between the gas traced by $C^{18}O$ and that traced by N_2H^+, indicating the dissipation of turbulence at higher densities. We find that the critical Bonnor-Ebert stability criterion is not a good indicator of the boundedness of our cores. We detect the pre-brown dwarf candidate Oph B-11 and find a flux density and mass consistent with previous work. We discuss regional variations in the nature of the cores and find further support for our previous hypothesis of a global evolutionary gradient across the cloud from southwest to northeast, indicating sequential star formation across the region.

Accepted by MNRAS

http://arxiv.org/pdf/1502.05858

Another deep dimming of the classical T Tauri star RW Aur A

Peter P. Petrov[1], Gösta F. Gahm[2], Anlaug A. Djupvik[3], Elena V. Babina[1], Svetlana A. Artemenko[1] and Konstantin N. Grankin[1]

[1] Crimean Astrophysical Observatory, p/o Nauchny, 298409 Republic of Crimea, Russia
[2] Stockholm Observatory, AlbaNova University Centre, Stockholm University, SE-106 91 Stockholm, Sweden
[3] Nordic Optical Telescope, Rambla José Ana Fernández Pérez 7, ES-38711 Breña Baja, Spain

E-mail contact: petrogen@rambler.ru

RW Aur A is a classical T Tauri star (CTTS) with an unusually rich emission line spectrum. In 2014 the star faded by about 3 magnitudes in the V band and went into a long-lasting minimum. In 2010 the star suffered from a similar

fading, although less deep. These events in RW Aur A are very unusual among the CTTS, and have been attributed to occultations by passing dust clouds.
In order to find out if any spectral changes took place after the last fading of RW Aur A we have obtained spectra of the two components of RW Aur, which is a visual binary. Photometry was made before and during the minimum.
The overall spectral signatures reflecting emission from accretion flows from disk to star did not change after the fading. However, blue-shifted absorption components related to the stellar wind had increased in strength in certain resonance lines, and the profiles and strengths, but not fluxes, of forbidden lines had become drastically different.
We conclude that the extinction through the obscuring cloud is very grey indicating the presence of large dust grains, but there are no traces of related absorbing gas. The cloud occults the star and the interior part of the stellar wind, but not the wind/jet further out. The dimming, that occurred in 2014, was not accompanied by changes in the accretion flows at the stellar surface. There is evidence that the structure and velocity pattern of the stellar wind did change significantly, and we speculate that large dust grains have been stirred up from the inclined disk into the line-of-sight through the interaction between an enhanced wind and the disk.

Accepted by Astronomy and Astrophysics

The formation of a quadruple star system with wide separation

Jaime E Pineda[1], Stella S. R. Offner[2,3], Richard J. Parker[4], Hector G. Arce[2], Alyssa A. Goodman[5], Paola Caselli[6], Gary A. Fuller[7], Tyler L. Bourke[5,8] and Stuartt A. Corder[9,10]

[1] Institute for Astronomy, ETH Zurich, Wolfgang-Pauli-Strasse 27, CH-8093 Zurich, Switzerland
[2] Department of Astronomy, Yale University, PO Box 208101, New Haven, Connecticut 06520-8101, USA.
[3] Department of Astronomy, University of Massachusetts, 710 North Pleasant Street, Amherst, Massachusetts 01003, USA.
[4] Astrophysics Research Institute, Liverpool John Moores University, 146 Brownlow Hill, Liverpool L3 5RF, UK
[5] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, Massachusetts 02138, USA
[6] Max-Planck-Institut fur extraterrestrische Physik (MPE), Giessenbachstrasse 1, D-85741 Garching, Germany.
[7] UK ARC Node, Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, Alan Turing Building, Oxford Road, University of Manchester, Manchester M13 9PL, UK.
[8] SKA Organisation, Jodrell Bank Observatory, Lower Withington, Macclesfield, Cheshire SK11 9DL, UK.
[9] Joint ALMA Observatory, Alonso de Cordova 3107, Vitacura, Santiago, Chile.
[10] National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, Virginia 22903, USA.

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

The initial multiplicity of stellar systems is highly uncertain. A number of mechanisms have been proposed to explain the origin of binary and multiple star systems, including core fragmentation, disk fragmentation and stellar capture. Observations show that protostellar and pre-main-sequence multiplicity is higher than the multiplicity found in field stars, which suggests that dynamical interactions occur early, splitting up multiple systems and modifying the initial stellar separations. Without direct, high-resolution observations of forming systems, however, it is difficult to determine the true initial multiplicity and the dominant binary formation mechanism. Here we report observations of a wide-separation (greater than 1,000 astronomical units) quadruple system composed of a young protostar and three gravitationally bound dense gas condensations. These condensations are the result of fragmentation of dense gas filaments, and each condensation is expected to form a star on a time-scale of 40,000 years. We determine that the closest pair will form a bound binary, while the quadruple stellar system itself is bound but unstable on timescales of 500,000 years (comparable to the lifetime of the embedded protostellar phase). These observations suggest that filament fragmentation on length scales of about 5,000 astronomical units offers a viable pathway to the formation of multiple systems.

Accepted by Nature

http://www.nature.com/nature/journal/v518/n7538/full/nature14166.html

Assessing molecular outflows and turbulence in the protostellar cluster Serpens South

Adele L. Plunkett[1], Hector G. Arce[1], Stuartt A. Corder[2], Michael M. Dunham[3], Guido Garay[4] and Diego Mardones[4]

[1] Department of Astronomy, Yale University, P.O. Box 208101, New Haven CT 06520, USA

[2] Joint ALMA Observatory, Av. Alonso de Cordova 3107, Vitacura, Santiago, Chile
[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS 78, Cambridge, MA 02138, USA
[4] Departamento de Astronomia, Universidad de Chile, Casilla 36-D, Santiago, Chile

E-mail contact: adele.plunkett *at* yale.edu

Molecular outflows driven by protostellar cluster members likely impact their surroundings and contribute to turbulence, affecting subsequent star formation. The very young Serpens South cluster consists of a particularly high density and fraction of protostars, yielding a relevant case study for protostellar outflows and their impact on the cluster environment. We combined CO $J = 1-0$ observations of this region using the Combined Array for Research in Millimeter-wave Astronomy (CARMA) and the Institut de Radioastronomie Millimétrique (IRAM) 30 m single dish telescope. The combined map allows us to probe CO outflows within the central, most active region at size scales of 0.01 pc to 0.8 pc. We account for effects of line opacity and excitation temperature variations by incorporating ^{12}CO and ^{13}CO data for the $J = 1-0$ and $J = 3-2$ transitions (using Atacama Pathfinder Experiment and Caltech Submillimeter Observatory observations for the higher CO transitions), and we calculate mass, momentum, and energy of the molecular outflows in this region. The outflow mass loss rate, force, and luminosity, compared with diagnostics of turbulence and gravity, suggest that outflows drive a sufficient amount of energy to sustain turbulence, but not enough energy to substantially counter the gravitational potential energy and disrupt the clump. Further, we compare Serpens South with the slightly more evolved cluster NGC 1333, and we propose an empirical scenario for outflow-cluster interaction at different evolutionary stages.

Accepted by The Astrophysical Journal

http://arxiv.org/pdf/1503.01111

SMA Observations of W3(OH) Complex: Physical and Chemical Differentiation between W3(H_2O) and W3(OH)

Sheng-Li Qin[1], Peter Schilke[2], Jingwen Wu[3], Yuefang Wu[4], Tie Liu[5], Ying Liu[6] and Álvaro Sánchez-Monge[2]

[1] Department of Astronomy, Yunnan University, and Key Laboratory of Astroparticle Physics of Yunnan Province, Kunming, 650091, China
[2] Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, D-50937 Köln, Germany
[3] Department of Physics and Astronomy, University of California, Los Angeles, CA 90095, USA
[4] Department of Astronomy, Peking University, Beijing, 100871, China
[5] Korea Astronomy and Space Science Institute 776, Daedeokdaero, Yuseong-gu, Daejeon, Republic of Korea 305-348
[6] Department of Physics and Hebei Advanced Thin Film Laboratory, Hebei Normal University, Shijiazhuang 050024, China

E-mail contact: slqin *at* bao.ac.cn

We report on the Submillimeter Array (SMA) observations of molecular lines at 270 GHz toward W3(OH) and W3(H_2O) complex. Although previous observations already resolved the W3(H_2O) into two or three sub-components, the physical and chemical properties of the two sources are not well constrained. Our SMA observations clearly resolved W3(OH) and W3(H_2O) continuum cores. Taking the advantage of the line fitting tool XCLASS, we identified and modeled a rich molecular spectrum in this complex, including multiple CH_3CN and CH_3OH transitions in both cores. HDO, C_2H_5CN, $O^{13}CS$, and vibrationally excited lines of HCN, CH_3CN, and CH_3OCHO were only detected in W3(H_2O). We calculate gas temperatures and column densities for both cores. The results show that W3(H_2O) has higher gas temperatures, and larger column densities than W3(OH) as previously observed, suggesting physical and chemical differences between the two cores. We compare the molecular abundances in W3(H_2O) to those in the Sgr B2(N) hot core, the Orion KL hot core and the Orion Compact Ridge, and discuss the chemical origin of specific species. An east-west velocity gradient is seen in W3(H_2O), and the extension is consistent with the bipolar outflow orientation traced by water masers and radio jets. A north-south velocity gradient across W3(OH) is also observed. However, with current observations we can not assure if the velocity gradients are caused by rotation, outflow or radial velocity differences of the sub-components in W3(OH).

Accepted by ApJ

http://arxiv.org/pdf/1502.04467

Protoplanetary disk lifetimes vs stellar mass and possible implications for giant planet populations

Álvaro Ribas[1,2,3], Hervé Bouy[2], and Bruno Merín[1,4]

[1] European Space Astronomy Centre (ESA), P.O. Box, 78, 28691 Villanueva de la Caada, Madrid, Spain
[2] Centro de Astrobiología, INTA-CSIC, P.O. Box - Apdo. de correos 78, Villanueva de la Cañada Madrid 28691, Spain
[3] Ingenieria y Servicios Aeroespaciales-ESAC, P.O. Box, 78, 28691 Villanueva de la Cañada, Madrid, Spain
[4] Herschel Science Centre, ESAC-ESA, P.O. Box, 78, 28691 Villanueva de la Cañada, Madrid, Spain

E-mail contact: aribas *at* cab.inta-csic.es

We study the dependence of protoplanetary disk evolution on stellar mass using a large sample of young stellar objects in nearby young star-forming regions. We update the protoplanetary disk fractions presented in our recent work (paper I of this series) derived for 22 nearby (<500 pc) associations between 1 and 100 Myr. We use a subsample of 1428 spectroscopically confirmed members to study the impact of stellar mass on protoplanetary disk evolution. We divide this sample into two stellar mass bins (2 $M_\odot$ boundary) and two age bins (3 Myr boundary), and use infrared excesses over the photospheric emission to classify objects in three groups: protoplanetary disks, evolved disks, and diskless. The homogeneous analysis and bias corrections allow for a statistically significant inter-comparison of the obtained results. We find robust statistical evidence of disk evolution dependence with stellar mass. Our results, combined with previous studies on disk evolution, confirm that protoplanetary disks evolve faster and/or earlier around high-mass (>2 $M_\odot$) stars. We also find a roughly constant level of evolved disks throughout the whole age and stellar mass spectra. We conclude that protoplanetary disk evolution depends on stellar mass. Such a dependence could have important implications for gas giant planet formation and migration, and could contribute to explaining the apparent paucity of hot Jupiters around high-mass stars.

Accepted by A&A

http://arxiv.org/pdf/1502.00631

Isolating the pre-main sequence in Collinder 34, NGC 3293, NGC 3766 and NGC 6231

T.A. Saurin[1], E. Bica[1], and C. Bonatto[1]

[1] Universidade Federal do Rio Grande do Sul, Departamento de Astronomia, CP 15051, RS, Porto Alegre 91501-970, Brazil

E-mail contact: tiago.saurin *at* ufrgs.br

We employed field star decontaminated 2MASS photometry to study four nearby optical embedded clusters – Collinder 34, NGC 3293, NGC 3766 and NGC 6231 – obtaining deep colour-magnitude diagrams and stellar radial density profiles. We found what seems to be pre-main sequences detached in different amounts from main sequences in these diagrams. The structural analysis of each cluster revealed different radial distributions for these two sequences. We argued that the detached evolutionary sequences in our sample may be evidence of sequential star formation. Finally, we compared the sample cluster parameters with those of other young clusters in the literature and point out evidence that NGC 3766 and NGC 6231 might be evolving to OB associations.

Accepted by MNRAS

http://arxiv.org/pdf/1502.00373

The unusual photometric variability of the PMS star GM Cep

E. H. Semkov[1], S. I. Ibryamov[1], S. P. Peneva[1], T. R. Milanov[2], K. A. Stoyanov[1], I. K. Stateva[1], D. P. Kjurkchieva[2], D. P. Dimitrov[1] and V. S. Radeva[2]

[1] Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences, 72 Tsarigradsko Shose blvd., BG-1784 Sofia, Bulgaria
[2] Department of Physics, Shumen University, 9700 Shumen, Bulgaria

E-mail contact: esemkov *at* astro.bas.bg

Results from $UBVRI$ photometric observations of the pre-main sequence star GM Cep obtained in the period April

2011 - August 2014 are reported in the paper. Presented data are a continuation of our photometric monitoring of the star started in 2008. GM Cep is located in the field of the young open cluster Trumpler 37 and over the past years it has been an object of intense photometric and spectral studies. The star shows a strong photometric variability interpreted as a possible outburst from EXor type in previous studies. Our photometric data for a period of over six years show a large amplitude variability ($\Delta V \sim 2.3$ mag) and several deep minimums in brightness are observed. The analysis of the collected multicolor photometric data shows the typical of UX Ori variables a color reversal during the minimums in brightness. The observed decreases in brightness have a different shape, and evidences of periodicity are not detected. At the same time, high amplitude rapid variations in brightness typical for the classical T Tauri stars also present on the light curve of GM Cep. The spectrum of GM Cep shows the typical of classical T Tauri stars wide Hα emission line and absorption lines of some metals. We calculate the outer radius of the Hα emitting region as 10.4±0.5 $R_\odot$ and the accretion rate as 1.8×10^{-7} $M_\odot$ yr^{-1}.

Accepted by PASA

http://arxiv.org/pdf/1502.07579

Catalog of dense cores in the Orion A giant molecular cloud

Yoshito Shimajiri[1,2,3], Y. Kitamura[4], F. Nakamura[2], M. Momose[5], M. Saito[2,3], T. Tsukagoshi[5], M. Hiramatsu[2], T. Shimoikura[6], K. Dobashi[6], C. Hara[7] and R. Kawabe[2]

[1] Laboratoire AIM, CEA/DSM-CNRS-Université Paris Diderot, IRFU/Service d'Astrophysique, CEA Saclay, F-91191 Gif-sur-Yvette, France

[2] National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

[3] Nobeyama Radio Observatory, 462-2 Nobeyama, Minamimaki, Minamisaku, Nagano 384-1305, Japan

[4] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan

[5] College of Science, Ibaraki University, 2-1-1 Bunkyo, Mito, Ibaraki 310-8512, Japan

[6] Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Koganei, Tokyo 184-8501, Japan

[7] The University of Tokyo, 7-3-1 Hongo Bunkyo, Tokyo 113-0033, Japan

E-mail contact: Yoshito.Shimajiri *at* cea.fr

We present Orion A giant molecular cloud core catalogs, which are based on 1.1 mm map with an angular resolution of 36 *arcsec* ($\sim$ 0.07 pc) and $C^{18}O$ (J=1–0) data with an angular resolution of 26.4 *arcsec* ($\sim$ 0.05 pc). We have cataloged 619 dust cores in the 1.1 mm map using the Clumpfind method. The ranges of the radius, mass, and density of these cores are estimated to be 0.01 – 0.20 pc, $0.6 - 1.2 \times 10^2$ $M_\odot$, and 0.3×10^4 - 9.2×10^6 cm^{-3}, respectively. We have identified 235 cores from the $C^{18}O$ data. The ranges of the radius, velocity width, LTE mass, and density are 0.13 – 0.34 pc, 0.31 – 1.31 km s^{-1}, 1.0 – 61.8 $M_\odot$, and $(0.8 - 17.5) \times 10^3$ cm^{-3}, respectively. From the comparison of the spatial distributions between the dust and $C^{18}O$ cores, four types of spatial relations were revealed: (1) the peak positions of the dust and $C^{18}O$ cores agree with each other (32.4% of the $C^{18}O$ cores), (2) two or more $C^{18}O$ cores are distributed around the peak position of one dust core (10.8% of the $C^{18}O$ cores), (3) 56.8% of the $C^{18}O$ cores are not associated with any dust cores, and (4) 69.3% of the dust cores are not associated with any $C^{18}O$ cores. The data sets and analysis are public.

Accepted by ApJS

http://arxiv.org/pdf/1502.03100

Circumstellar discs in Galactic centre clusters: Disc-bearing B-type stars in the Quintuplet and Arches clusters

Andrea Stolte[1], Benjamin Hußmann[1], Christoph Olczak[2], Wolfgang Brandner[3], Maryam Habibi[1,4], Andrea M. Ghez[5], Mark R. Morris[5], Jessica R. Lu[6], William I. Clarkson[7] and Jay Anderson[8]

[1] Argelander Institut für Astronomie, Universität Bonn, Auf dem Hügel 71, 53121 Bonn, Germany

[2] Astronomisches Recheninstitut, Universität Heidelberg, Mönchhofstr. 12-14, 69120 Heidelberg, Germany

[3] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany

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

[5] Division of Astronomy and Astrophysics, UCLA, Los Angeles, CA 90095-1547, USA
[6] Institute for Astronomy, University of Hawai'i, 2680 Woodlawn Drive, Honolulu, HI 96822, USA
[7] Department of Natural Sciences, University of Michigan-Dearborn, 125 Science Building, 4901 Evergreen Road, Dearborn, MI 48128, USA
[8] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

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

We investigate the circumstellar disc fraction as determined from L-band excess observations of the young, massive Arches and Quintuplet clusters residing in the central molecular zone of the Milky Way. The Quintuplet cluster was searched for L-band excess sources for the first time. We find a total of 26 excess sources in the Quintuplet cluster, and 21 sources with L-band excesses in the Arches cluster, of which 13 are new detections. With the aid of proper motion membership samples, the disc fraction of the Quintuplet cluster could be derived for the first time to be $4.0 \pm 0.7\%$. There is no evidence for a radially varying disc fraction in this cluster. In the case of the Arches cluster, a disc fraction of $9.2 \pm 1.2\%$ approximately out to the cluster's predicted tidal radius, $r < 1.5$ pc, is observed. This excess fraction is consistent with our previously found disc fraction in the cluster in the radial range $0.3 < r < 0.8$ pc. In both clusters, the host star mass range covers late A- to early B-type stars, $2 < M < 15\,M_\odot$, as derived from J-band photospheric magnitudes. We discuss the unexpected finding of dusty circumstellar discs in these UV intense environments in the context of primordial disc survival and formation scenarios of secondary discs. We consider the possibility that the L-band excess sources in the Arches and Quintuplet clusters could be the high-mass counterparts to T Tauri pre-transitional discs. As such a scenario requires a long pre-transitional disc lifetime in a UV intense environment, we suggest that mass transfer discs in binary systems are a likely formation mechanism for the B-star discs observed in these starburst clusters.

Accepted by Astronomy & Astrophysics

http://arxiv.org/pdf/1502.03681

Discovery of four periodic methanol masers and updated light curve for a further one

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

[1] Centre for Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Torun, Poland

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

We report the discovery of 6.7 GHz methanol maser periodic flares in four massive star forming regions and the updated light curve for the known periodic source G22.357+0.066. The observations were carried out with the Torun 32 m radio telescope between June 2009 and April 2014. Flux density variations with period of 120 to 245 d were detected for some or all spectral features. A variability pattern with a fast rise and relatively slow fall on time-scale of 30−60 d dominated. A reverse pattern was observed for some features of G22.357+0.066, while sinusoidal-like variations were detected in G25.411+0.105. A weak burst lasting ∼520 d with the velocity drift of $0.24\,\mathrm{km\,s^{-1}\,yr^{-1}}$ occurred in G22.357+0.066. For three sources for which high resolution maps are available, we found that the features with periodic behaviour are separated by more than 500 au from those without any periodicity. This suggests that the maser flares are not triggered by large-scale homogeneous variations in either the background seed photon flux or the luminosity of the exciting source and a mechanism which is able to produce local changes in the pumping conditions is required.

Accepted by MNRAS

http://arXiv.org/pdf/1502.03373

First Detection of [C I] $^3P_1$–$^3P_0$ Emission from a Protoplanetary Disk

Takashi Tsukagoshi[1], Munetake Momose[1], Masao Saito[2], Yoshimi Kitamura[3], Yoshito Shimajiri[4] and Ryohei Kawabe[5]

[1] College of Science, Ibaraki University, Bunkyo 2-1-1, Mito 310-8512, Japan
[2] Nobeyama Radio Observatory, Minamimaki, Minamisaku, Nagano 384-1305, Japan
[3] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Yoshinodai 3-1-1, Sagamihara, Kanagawa 229-8510, Japan

[4] Laboratoire AIM, CEA/DSM-CNRS-Université Paris, Diderot, IRFU/Service d'Astrophysique, CEA, Saclay, F-91191 Gif-sur-Yvette Cedex, France
[5] National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan

E-mail contact: ttsuka *at* mx.ibaraki.ac.jp

We performed single point [C I] $^3P_1$–$^3P_0$ and CO J=4–3 observations toward three T Tauri stars, DM Tau, LkCa 15, and TW Hya, using the Atacama Large Millimeter/submillimeter Array (ALMA) Band 8 qualification model receiver installed on the Atacama Submillimeter Telescope Experiment (ASTE). Two protostars in the Taurus L1551 region, L1551 IRS 5 and HL Tau, were also observed. We successfully detected [C I] emission from the protoplanetary disk around DM Tau as well as the protostellar targets. The spectral profile of the [C I] emission from the protoplanetary disk is marginally single-peaked, suggesting that atomic carbon (C) extends toward the outermost disk. The detected [C I] emission is optically thin and the column densities of C are estimated to be $<\sim 10^{16}$ cm^{-2} and $\sim 10^{17}$ cm^{-2} for the T Tauri star targets and the protostars, respectively. We found a clear difference in the total mass ratio of C to dust, M(C)/M(dust), between the T Tauri stars and protostellar targets; the M(C)/M(dust) ratio of the T Tauri stars is one order of magnitude smaller than that of the protostars. The decrease of the estimated M(C)/M(dust) ratios for the disk sources is consistent with a theoretical prediction that the atomic C can survive only in the near surface layer of the disk and C$^+$/C/CO transition occurs deeper into the disk midplane.

Accepted by Astrophysical Journal Letters

http://arxiv.org/pdf/1503.00807

Tracing the Conversion of Gas into Stars in Young Massive Cluster Progenitors

D.L. Walker[1], S.N. Longmore[1], N. Bastian[1], J.M.D. Kruijssen[2], J.M. Rathborne[3], J.M. Jackson[4], J.B. Foster[5] and Y. Contreras[3]

[1] Astrophysics Research Institute, Liverpool John Moores University, IC2, 146 Brownlow Hill, Liverpool, L3 5RF, United Kingdom
[2] Max-Planck Institut fur Astrophysik, Karl-Schwarzschild-Strasse 1, 85748, Garching, Germany
[3] CSIRO Astronomy and Space Science, Epping, Sydney, Australia
[4] Institute for Astrophysical Research, Boston University, Boston, MA 02215, USA
[5] Yale Center for Astronomy and Astrophysics, New Haven, CT 06520, USA

E-mail contact: D.L.Walker *at* 2009.ljmu.ac.uk

Whilst young massive clusters (YMCs; $M \gtrsim 10^4$ $M_\odot$, age $\lesssim$100 Myr) have been identified in significant numbers, their progenitor gas clouds have eluded detection. Recently, four extreme molecular clouds residing within 200 pc of the Galactic centre have been identified as having the properties thought necessary to form YMCs. Here we utilise far-IR continuum data from the Herschel Infrared Galactic Plane Survey (HiGAL) and millimetre spectral line data from the Millimetre Astronomy Legacy Team 90 GHz Survey (MALT90) to determine their global physical and kinematic structure. We derive their masses, dust temperatures and radii and use virial analysis to conclude that they are all likely gravitationally bound – confirming that they are likely YMC progenitors. We then compare the density profiles of these clouds to those of the gas and stellar components of the Sagittarius B2 Main and North proto-clusters and the stellar distribution of the Arches YMC. We find that even in these clouds – the most massive and dense quiescent clouds in the Galaxy – the gas is not compact enough to form an Arches-like ($M = 2 \times 10^4$ $M_\odot$, $R_{\rm eff} = 0.4$ pc) stellar distribution. Further dynamical processes would be required to condense the resultant population, indicating that the mass becomes more centrally concentrated as the (proto)-cluster evolves. These results suggest that YMC formation may proceed hierarchically rather than through monolithic collapse.

Accepted by MNRAS

http://arxiv.org/pdf/1502.03822

Are the majority of Sun-like stars single?

A. P. Whitworth[1] and O. Lomax[1]

[1] School of Physics and Astronomy, Cardiff University, Cardiff CF24 3AA, Wales, UK

E-mail contact: anthony.whitworth *at* astro.cf.ac.uk

It has recently been suggested that, in the field, ~56% of Sun-like stars ($0.8\,M_\odot < M_\star < 1.2\,M_\odot$) are single. We argue here that this suggestion may be incorrect, since it appears to be based on the multiplicity frequency of systems with Sun-like primaries, and therefore takes no account of Sun-like stars that are secondary (or higher-order) components in multiple systems. When these components are included in the reckoning, it seems likely that only ~46% of Sun-like stars are single. This estimate is based on a model in which the system mass function has the form proposed by Chabrier, with a power-law Salpeter extension to high masses; there is a flat distribution of mass ratios; and the probability that a system of mass M is a binary is $0.50 + 0.46\log_{10}(M/M_\odot)$ for $0.08\,M_\odot \leq M \leq 12.5\,M_\odot$, 0 for $M < 0.08\,M_\odot$, and 1 for $M > 12.5\,M_\odot$. The constants in this last relation are chosen so that the model also reproduces the observed variation of multiplicity frequency with primary mass. However, the more qualitative conclusion, that a minority of Sun-like stars are single, holds up for virtually all reasonable values of the model parameters. Parenthetically, it is still likely that the majority of *all* stars in the field are single, but that is because most M Dwarfs probably are single.

Accepted by MNRAS

http://arxiv.org/pdf/1502.04018

The Massive Star Population of Cygnus OB2

Nicholas J. Wright[1], Janet E. Drew[1] and Michael Mohr-Smith[1]

[1] Centre for Astrophysics Research, University of Hertfordshire, College Lane, Hatfield, AL10 9AB, UK

E-mail contact: nick.nwright *at* gmail.com

We have compiled a significantly updated and comprehensive census of massive stars in the nearby Cygnus OB2 association by gathering and homogenising data from across the literature. The census contains 169 primary OB stars, including 52 O-type stars and 3 Wolf-Rayet stars. Spectral types and photometry are used to place the stars in a Hertzprung-Russell diagram, which is compared to both non-rotating and rotating stellar evolution models, from which stellar masses and ages are calculated. The star formation history and mass function of the association are assessed, and both are found to be heavily influenced by the evolution of the most massive stars to their end states. We find that the mass function of the most massive stars is consistent with a 'universal' power-law slope of $\Gamma = 1.3$. The age distribution inferred from stellar evolutionary models with rotation and the mass function suggest the majority of star formation occurred more or less continuously between 1 and 7 Myr ago, in agreement with studies of low- and intermediate mass stars in the association. We identify a nearby young pulsar and runaway O-type star that may have originated in Cyg OB2 and suggest that the association has already seen its first supernova. Finally we use the census and mass function to calculate the total mass of the association of $16500^{+3800}_{-2800}\ M_\odot$, at the low end, but consistent with, previous estimates of the total mass of Cyg OB2. Despite this Cyg OB2 is still one of the most massive groups of young stars known in our Galaxy making it a prime target for studies of star formation on the largest scales.

Accepted by MNRAS

http://arxiv.org/pdf/1502.05718

Radio Continuum Observations of the Galactic Center: Photoevaporative Proplyd-like Objects near Sgr A*

F. Yusef-Zadeh[1], D. A. Roberts[1], M. Wardle[2], W. Cotton[3], R. Schödel[4] and M. J. Royster[1]

[1]Department of Physics and Astronomy and CIERA, Northwestern University, Evanston, IL 60208, USA
[2]Department of Physics and Astronomy, Macquarie University, Sydney NSW 2109, Australia
[3]National Radio Astronomy Observatory, Charlottesville, VA 22903, USA
[4]Instituto de Astfisica de Andalucia (CSIC), Glorieta de la Astronomia S/N, 18008 Granada, Spain

E-mail contact: zadeh*at*northwestern.edu

We present radio images within 30″ of Sgr A* based on recent VLA observations at 34 GHz with 7.8 μJy sensitivity and resolution $\sim 88 \times 46$ milliarcseconds (mas). We report 44 partially resolved compact sources clustered in two regions in the E arm of ionized gas that orbits Sgr A*. These sources have size scales ranging between $\sim$ 50 and 200 mas (400 to 1600 AUs), and a bow-shock appearance facing the direction of Sgr A*. Unlike the bow-shock sources previously identified in the near-IR but associated with massive stars, these 34 GHz sources do not appear to have near-IR

counterparts at 3.8 μm. We interpret these sources as a candidate population of photoevaporative protoplanetary disks (proplyds) that are associated with newly formed low mass stars with mass loss rates $\sim 10^{-7} - 10^{-6}$ $M_{\odot}$ yr^{-1} and are located at the edge of a molecular cloud outlined by ionized gas. The disks are externally illuminated by strong Lyman continuum radiation from the ∼100 OB and WR massive stars distributed within $10''$ of Sgr A*. The presence of proplyds implies current in-situ star formation activity near Sgr A* and opens a window for the first time to study low mass star, planetary and brown dwarf formations near a supermassive black hole.

Accepted by ApJL

http://arxiv.org/pdf/1502.03109

Abstracts of recently accepted major reviews

Earth and Terrestrial Planet Formation

Seth A. Jacobson[1,2] and Kevin J. Walsh[3]

[1] Bayerisches Geoinstitut, Universität Bayreuth, 95440 Bayreuth, Germany
[2] Laboratoire Lagrange, Observatoire de la Côte d'Azur, 06304 Nice, France
[3] Planetary Science Directorate, Southwest Research Institute, 80302 Boulder, CO, USA

E-mail contact: seth.jacobson *at* oca.eu

The growth and composition of Earth is a direct consequence of planet formation throughout the Solar System. We discuss the known history of the Solar System, the proposed stages of growth and how the early stages of planet formation may be dominated by pebble growth processes. Pebbles are small bodies whose strong interactions with the nebula gas lead to remarkable new accretion mechanisms for the formation of planetesimals and the growth of planetary embryos.
Many of the popular models for the later stages of planet formation are presented. The classical models with the giant planets on fixed orbits are not consistent with the known history of the Solar System, fail to create a high Earth/Mars mass ratio, and, in many cases, are also internally inconsistent. The successful Grand Tack model creates a small Mars, a wet Earth, a realistic asteroid belt and the mass-orbit structure of the terrestrial planets.
In the Grand Tack scenario, growth curves for Earth most closely match a Weibull model. The feeding zones, which determine the compositions of Earth and Venus follow a particular pattern determined by Jupiter, while the feeding zones of Mars and Theia, the last giant impactor on Earth, appear to randomly sample the terrestrial disk. The late accreted mass samples the disk nearly evenly.

Accepted by Early Earth an AGU Monograph

http://arxiv.org/pdf/1502.03852

New Jobs

Doctoral students in Astronomy and Astrophysics at Lund University - Formation of asteroids and exoplanets

Research on the formation of planetary systems is in rapid development, fuelled by the wealth of new observational data and the advent of more and more powerful supercomputers. Funding has been obtained to hire three PhD students in theoretical and computational astrophysics at Lund University.

The PhD students will work within the subjects: (1) the formation of super-Earths and gas-giant planets, (2) the formation and orbital evolution of asteroids and their impact history on Earth, and (3) spontaneous particle clumping and planetesimal formation. Together with the other group members, currently 3 postdocs and 5 PhD students, the new PhD students will work in an inspiring environment towards the common goal of understanding the formation of planetary systems around the Sun and other stars.

Candidates should send a curriculum vitae and a brief statement of research interest. The application should also include the names, telephone numbers and e-mail addresses of two persons who have agreed to serve as a reference for the applicant. Note that reference letters should not be sent to us in connection with the application; we will contact the reference persons when required.

Closing date: 22 May 2015

Contact Anders Johansen (anders@astro.lu.se) for more information.

Apply online at https://lu.mynetworkglobal.com/en/what:job/jobID:57728/

Postdoctoral Researcher in Planet Formation

Applications are invited for a Postdoctoral Researcher to work with Professors Fred Ciesla (University of Chicago) and Ted Bergin (University of Michigan) on the chemical evolution of protoplanetary disks and primitive materials. The primary research tasks will focus on coupling the dynamical evolution of solids in protoplanetary disks with chemical evolution models to evaluate the histories of volatiles and organics during the early stages of planet formation.

The position is supported through the "Earths in Other Solar Systems" program (EOS), a multi-institutional astrobiology research consortium, funded through NASA's Nexus for Exoplanet System Studies research initiative. The successful applicant will be full member of the NExSS/EOS team. Details on the EOS project can be found at the team's website: http://eos-nexus.org. Additional resources will be made available through the NSF INSPIRE program.

The work will be largely computational, requiring proficiency in numerical modeling. A PhD in astronomy, astrophysics, or planetary sciences is required by the date of employment. The term of employment is initially for one year, but is renewable annually. The position will be based at the University of Chicago with Fred Ciesla, but will involve regular travel to the University of Michigan for collaborations and training with Ted Bergin and his group.

To apply, please send a cover letter, a CV, a brief statement of past and current research interests, and the contact information for 3 people who are willing to provide recommendations in support of the application. Materials should be sent by email to fciesla@uchicago.edu. Informal inquiries are welcomed.

Two Postdoctoral positions in the ERC group "From Cloud to Star Formation" in the Planet and Star Formation Department at the Max Planck Institute for Astronomy (MPIA) in Heidelberg (Reference number 15-04)

The Max Planck Institute for Astronomy (MPIA) in Heidelberg is seeking two ambitious, highly qualified postdoctoral researchers to work in a newly established ERC group led by Henrik Beuther that targets the formation processes of molecular clouds and high-mass stars. One postdoc will work in the context of a large program conducted at the Jansky Very Large Array designed to study cloud formation and feedback processes: THOR: The HI/OH/Recombination line survey of the Milky Way. The other postdoc will focus on a large program at the IRAM Plateau de Bure Interferometer addressing the fragmentation and kinematic processes during the birth of the most massive stars: Fragmentation and disk formation during high-mass star formation. The candidates are expected to spend ∼50% of their research time to projects that are related to the respective large programs.

The Planet and Star Formation Department at MPIA is pursuing a wide range of astrophysical research along the lines of star and planet formation, encompassing large observing programs, instrument development, and theoretical modelling (see http://www.mpia.de for details). In addition to the ERC group research within the above outlined large programs, the successful candidates will also have access to the Large Binocular Telescope (LBT), the 2.2m and 3.5m telescopes on Calar Alto, to the Very Large Telescope, the Very Large Telescope Interferometer facility, and the APEX sub-millimeter telescope in Chile. MPIA astronomers also extensively use the 2.2m MPG telescope on La Silla and the IRAM and ALMA facilities. MPIA is also a Co-I of the Matisse and Gravity instruments for the VLTI as well as of METIS for the ELT and MIRI for JWST.

Applicants should have a PhD in astronomy, astrophysics, or a closely related field, and ideally some background in the research of the interstellar medium and star formation. Furthermore, experience in mm/radio interferometry is considered an asset. The appointment will be for an initial period of three years, with a potential extension to five years, and MPIA provides funds for publications, travel, etc.. The positions are available from Oct. 2015 and will be remunerated according to the German TVöD scheme in level E13/E14. Interested candidates should send a curriculum vitae, publication list, and a brief statement of research interests by 15th April, 2015. They should also arrange for three letters of reference to be provided separately by the same date. All applications and reference letters need to be submitted using our online application system at:

https://s-lotus.gwdg.de/mpg/mhas/psf-pd-15-04-in.nsf/portal

Candidates should first register with our online system to generate a registration code, which must be sent to referees for letter submission. Please concatenate CV, publication list, and research statement into a single PDF file.

For scientific enquires please contact: Henrik Beuther (beuther@mpia.de)

For submission enquires please contact: Sandra Berner (berner@mpia.de)

The Max Planck Society is an equal opportunity employer. Applications from women, disabled people and minority groups are particularly welcome. The MPIA supports its employees in their search for suitable child care institutions.

Call for applications for the position of Special Postdoctoral Researcher (SPDR) for FY 2016

RIKEN is currently accepting applications for the FY 2016 Special Postdoctoral Researcher (SPDR) Program, from young, creative, independent researchers who will be a powerful force in furthering RIKEN's research activities.

RIKEN is Japan's largest comprehensive research institution renowned for high-quality research in a diverse range of scientific disciplines. Founded in 1917 as a private research foundation in Tokyo, RIKEN has grown rapidly in size and scope, today encompassing a network of world-class research centers and institutes across Japan.

Note that previous Foreign Postdoctoral Researcher (FPR) program has been merged to the SPDR program from FY2016.

Total number of openings is about 60.

Application deadline is April 30 (Thur.), 2015

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For details, see the web page,
http://www.riken.jp/en/careers/programs/spdr/career2016/

Two of the astronomy & astrophysics groups which accept the applications are

* Star and Planet Formation Lab.
(New Lab. lead by Nami Sakai; Homepage will be open on 1st Apr,
inside the following page. http://www.riken.jp/en/research/pilist/?initial=S)

* Computational Astrophysics Laboratory
http://www.riken.jp/en/research/labs/chief/comput_astro/

Feel free to contact each team-leader by e-mail for further questions.

Nami Sakai
Associate Chief Scientist, RIKEN(from 1st Apr.)
nami@taurus.phys.s.u-tokyo.ac.jp

Exchanging mass, momentum, and ideas: Connecting accretion and outflows in Young Stellar Objects

2015 October 27 to 29, ESA/ESTEC, The Netherlands

Continuous progress is being made in our understanding of the accretion and outflow processes, observationally, theoretically and via simulations and yet, the physical link between these processes remains poorly understood.

The time is right to review what we know about accretion, outflows and their relation, and explore how we can move closer to understanding the link and their role in the global evolution of angular momentum in disks. We are organising the workshop "Exchanging Mass, Momentum and Ideas: Connecting Accretion and Outflows in YSOs", which will be held over 3 days at ESA/ESTEC, the Netherlands, from the 27th to 29th October 2015. It will consist of both invited and contributed talks, with ample discussion time and space for posters.

The main topics of discussion will be:
- Inner-disk processes: magnetospheric accretion, jet launching, magnetic fields, spatially unresolved observations, short time variability
- Outer-disk processes: large scale outflows, viscous evolution, disk winds, spatially resolved observations, long-term evolution
- Angular momentum evolution of disks
- Current and future observing facilities

Further information can be found on the workshop website:

http://www.cosmos.esa.int/web/accretion-outflow-workshop.

The list of **confirmed invited speakers** includes:
- Silvia Alencar (UFMG, Brazil)
- Xuening Bai (CfA, USA)
- Ilaria Pascucci (University of Arizona, USA)
- Catherine Dougados (IPAG, France)
- Geoffroy Lesur (IPAG, France)
- Claudio Zanni (OATO, Italy)

SOC: Jerome Bouvier (IPAG, France), Sylvie Cabrit (Observatoire de Paris, France), Lee Hartmann (University of Michigan, USA), and Antonella Natta (INAF/Arcetri, Italy & DIAS, Ireland)

Organizers: Grainne Costigan (Leiden Observatory), Carlo Felice Manara (ESA/ESTEC), Christian Schneider (ESA/ESTEC)

The number of participants will be limited to facilitate group discussions and exchange of ideas, we thus invite you to register early to avoid disappointment.

Summary of Upcoming Meetings

45th "Saas-Fee Advanced Course":
From Protoplanetary Disks to Planet Formation
15-20 March 2015, Switzerland
http://isdc.unige.ch/sf2015

The Soul of Massive Star Formation
15 - 20 March 2015 Puerto Varas, Chile
http://www.das.uchile.cl/msf2015/

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

Habitability in the Universe: From the Early Earth to Exoplanets
23 - 27 March 2015, Porto, Portugal
http://www.iastro.pt/research/conferences/life-origins2015/

Milky Way Astrophysics from Wide-Field Surveys
30 March - 1 April 2015, London, Burlington House at the RAS, UK
http://astro.kent.ac.uk/~df/gp/index.html

Cloudy Workshop
4 - 8 May 2015 Warsaw, Poland
http://cloud9.pa.uky.edu/~gary/cloudy/CloudySummerSchool/

Exoplanets in Lund 2015
6 - 8 May 2015 Lund, Sweden
http://www.astro.lu.se/lundexoplanets2015

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

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

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

The Formation and Destruction of Molecular Clouds
22 - 23 June 2015 Tenerife, Spain
http://eas.unige.ch/EWASS2015/session.jsp?id=S6

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

Gordon Research Conference on Origins of Solar Systems
28 June - 3 July 2015
http://www.grc.org/programs.aspx?id=12345

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

The Stellar IMF at Low Masses: A Critical Look at Variations and Environmental Dependencies
29 June - 1 July 2015 Baltimore, Maryland, USA
http://www.stsci.edu/institute/conference/stellar-imf/

From super-Earths to brown dwarfs: Who's who
29 June - 3 July 2015 Paris, France
http://www.iap.fr/col2015

Orion (un)plugged
1-3 + 6-8 July 2015 Vienna, Austria
https://www.univie.ac.at/alveslab/orion_unplugged/

From Interstellar Clouds to Star-forming Galaxies: Universal Processes?
3 - 7 August 2015 http://astronomy2015.org/symposium_315

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

6th Zermatt ISM Symposium: Conditions and Impact of Star Formation - From Lab to Space
7 - 11 September 2015 Zermatt, Switzerland
http://www.astro.uni-koeln.de/zermatt2015

Exchanging Mass, Momentum and Ideas: Connecting Accretion and Outflows in Young Stellar Objects
27 - 29 October 2015 Noordwijk, The Netherlands
http://www.cosmos.esa.int/web/accretion-outflow-workshop **Extreme Solar Systems III**
29 November - 4 December 2015 Hawaii, USA
http://ciera.northwestern.edu/Hawaii2015.php

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

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

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

Short Announcements

Fizeau exchange visitors program - call for applications

Dear colleagues!

The Fizeau exchange visitors program in optical interferometry funds (travel and accommodation) visits of researchers to an institute of his/her choice (within the European Community) to perform collaborative work and training on one of the active topics of the European Interferometry Initiative. The visits will typically last for one month, and strengthen the network of astronomers engaged in technical, scientific and training work on optical/infrared interferometry. The program is open for all levels of astronomers (Ph.D. students to tenured staff), non-EU based missions will only be funded if considered essential by the Fizeau Committee. Applicants are strongly encouraged to seek also partial support from their home or host institutions.

The deadline for applications is March 15. Fellowships can be awarded for missions starting in May.

NOTE: a special Fizeau call will be issued in late April for financial support requests for the VLTI school 2015 in Cologne: http://www.astro.uni-koeln.de/vltischool2015

Further informations and application forms can be found at www.european-interferometry.eu

The program is funded by OPTICON/FP7.

Please distribute this message also to potentially interested colleagues outside of your community!

Looking forward to your applications,
Josef Hron & Laszlo Mosoni
(for the European Interferometry Initiative)

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.