THE STAR FORMATION NEWSLETTER

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

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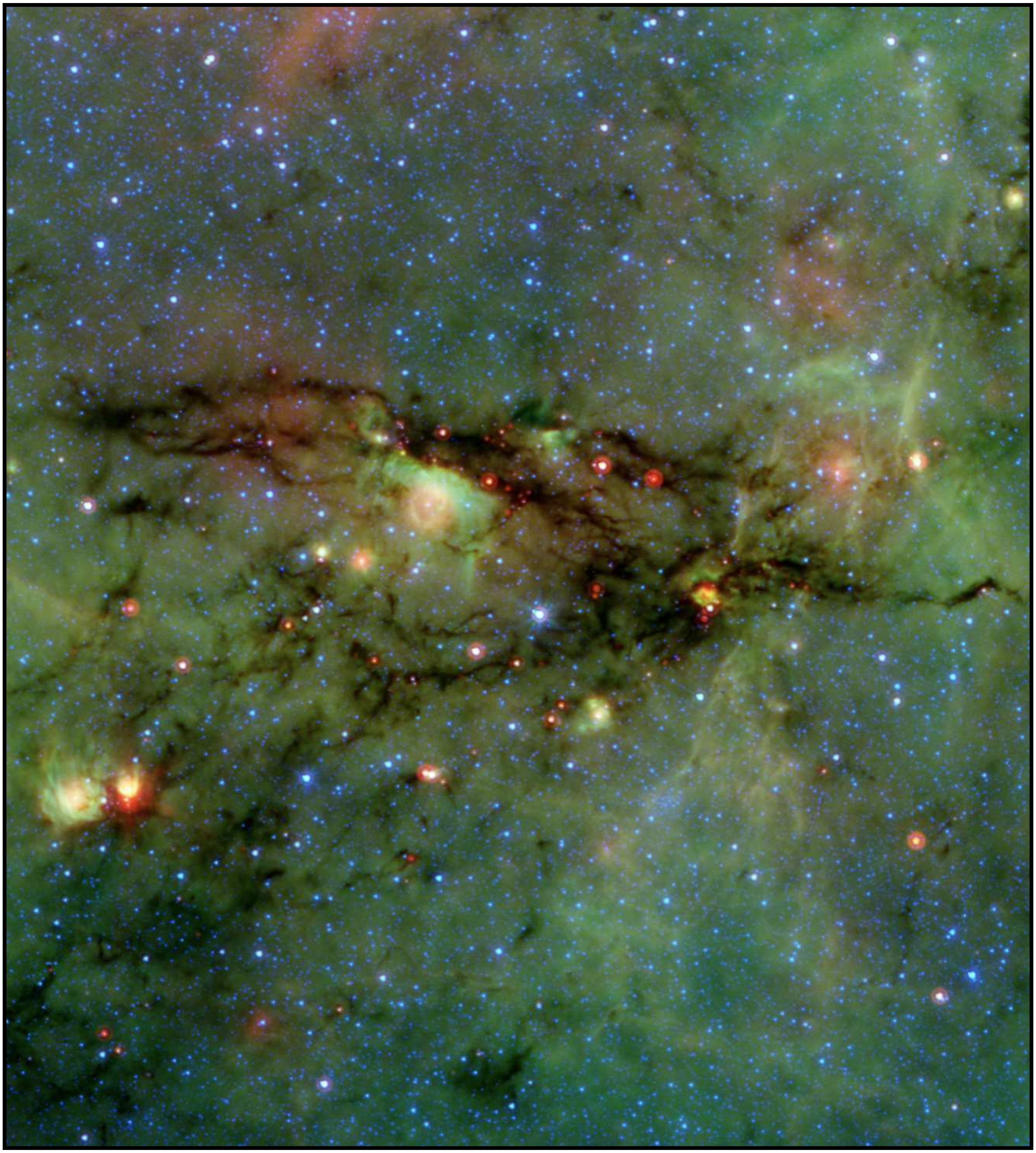
Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)



The Star Formation Newsletter

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

Newsletter Archive

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List of Contents

Cover Picture

In the giant molecular cloud that hosts the well known young cluster and HII region M17, Spitzer has found a dense dark cloud, M17SWex, which is actively forming young stars. The image is a composite of images from IRAC and MIPS, blue is 3.6 μm, green is 8 μm, and red is 24 μm.

Courtesy NASA/JPL-Caltech/M. Povich

Submitting your abstracts

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

Steven Stahler

in conversation with Bo Reipurth

Q: *You have a straight physics background. How did astronomy enter the picture?*

A: As an undergraduate, I was passionate about philosophy, although my major field of study was physics. I was heavily influenced by Bertrand Russell, both his analytic philosophy and his social views. Reading Russell's crystalline prose also taught me how to write. When I began physics graduate school at Berkeley, my goal was to apply this subject to the biggest questions. The only person doing general relativity was a mathematician, which I am not. I chose to work instead with Frank Shu in the Astronomy Department on the evolution of protostars. Frank himself was just entering the relatively young field of star formation. I took many courses in physics, but only a few in astronomy, picking up what I needed through reading. To this day, I consider myself a physicist at heart.

In my thesis and the resulting papers, Frank and I studied protostars in a new way. Previous researchers had emphasized cloud collapse, with the central star appearing as a biproduct of that process. We concentrated on the star itself, using the same techniques that had been used for other evolutionary phases. We made several discoveries, such as the fact that deuterium fuses with hydrogen even at this early time.

Q: *Among your first publications was an influential series of papers on Population III stars. What sparked this excursion into the early Universe?*

A: After completing my thesis in 1980, I obtained a postdoctoral fellowship at Cornell. There I met two people, at opposite stages in their respective careers, who played important roles in my life – Ed Salpeter and Francesco Palla. Thinking about the first stars, Ed wanted to know how molecular clouds arose in the absence of metals. A decade earlier, he and Dave Hollenbach had worked out how molecular hydrogen forms on grain surfaces in the present-day Universe. With Ed's guidance, Francesco and I did a fairly simple numerical calculation, and quickly found that, at sufficiently high density, the three-body combination of neutral hydrogen atoms efficiently produces the molecule. We also estimated, using a Jeans-type argument, the masses of the first stars produced. Since that time, many others have studied this topic in far greater detail. I am happy that the "triple hydrogen" reaction has continued to play a key role.

Q: *The discovery of the stellar birthline was another early achievement in your career. How did that idea develop?*

A: In the fall of 1982, I began a second postdoctoral position at Harvard. Phil Myers, who had arrived at the Center for Astrophysics a short time earlier, one day asked me to calculate the radii of a few dozen T Tauri stars in Taurus. After doing this, I placed these stars in the HR diagram, using a standard set of pre-main-sequence evolutionary tracks. To my surprise, the stars fell on or just below a well-defined locus. At this time, it was commonly thought that such young objects could have very large initial sizes. However, I soon found that the T Tauri stars in other regions had a similar distribution in the diagram as those in Taurus. Within a week, I came up with two arguments explaining the existence and location of the upper envelope. First, I showed that the observed maximum radius of a pre-main-sequence star at each mass closely matched the theoretical mass-radius relation for accreting protostars that I had calculated in my thesis. The second, and stronger, argument, concerned the star formation histories of regions like Taurus. I demonstrated that, if young stars do *not* have such a stringent upper limit to their radii, then the histories of all such regions would be odd, with formation activity inexplicably halting in the recent past. I vividly remember when this second argument came to me. That was a powerful experience, the feeling that I had been allowed a glimpse of how Nature works.

Over the next several years, I came back to this topic several times. In 1988, I showed that the protostar mass-radius relation, and hence the location of the birthline in the HR diagram, is insensitive to the infall rate building up the star's mass. The reason is that energy released by internal deuterium fusion swells the star as it gains mass. In 1990, Francesco and I calculated protostar evolution for intermediate-mass stars. Plotting out the extended birthline, we found that it accurately described the upper envelope of Herbig Ae and Be stars. These were satisfying results, but still incomplete. Eventually, when we have a fuller understanding of protostellar collapse, including rotation and magnetic fields, the subject should be revisited.

Q: *During the 1980s, you and Francesco coauthored a number of papers on early stellar evolution. After that, you branched out to other topics, such as outflows and binaries. What triggered those subsequent interests?*

A: In the early 1990s, Francesco and I began to collaborate on *The Formation of Stars*, the first graduate-level textbook in the field. This mammoth undertaking eventually consumed a decade. We covered a vast array of topics and learned a great deal. I was constantly tempted to break off from writing and help fill in what seemed to be obvious gaps. Early on, I read about optical stellar jets and molecular outflows. At the time, these were treated as unrelated phenomena. I sensed they were not, as did, independently, Jorge Cantó and Alex Raga. In 1994, I published my own favorite paper of those years, entitled *The Kinematics of Molecular Outflows.* I used the observational data to argue that (1) outflows are cloud gas driven by jet-like stellar winds, and (2) the pattern of velocities in outflows shows that they are being entrained, or dragged along, by the jets. In retrospect, I think this entrainment model applies best to the relatively narrow outflows associated with Class 0 sources.

Q: *You also began studying disks during that time.*

A: Yes, my first paper on protostellar disks was also in 1994. My colleagues and I found that there should be a dense, turbulent ring surrounding the star, where streams of gas, racing inward through the disk plane, collide and shock. Interior to this ring is a denser disk that transfers mass to the star. For two decades, there were no observational data bearing on this model. Then came ALMA. Since 2014, Nami Sakai and colleagues have observed the Class 0 source L1527 IRS in Taurus. They have actually imaged the ring, as well as the other structures predicted – a very exciting development.

Q: *What about binaries? You discussed these quite extensively in the book.*

A: Actually, my first serious foray into the world of binaries came later. About 10 years ago, I was teaching a graduate course in astrophysical fluid dynamics. To educate myself, I read James Lighthill's brilliant book, *Waves in Fluids*, which contains an elegant treatment of sound wave generation by spatially compact sources. It occurred to me that a binary star embedded in dense gas should indeed emit sound waves. Viewed from a distance, the binary would constitute, in Lighthill's scheme, a quadrupole source. Moreover, if I could calculate the angular momentum transported by these waves, then I would also obtain the torque acting on the binary. This torque actually arises from dynamical friction, but direct calculation of the friction force is cumbersome and untrustworthy. In 2010, I accomplished these goals, and found the orbital decay of a binary inside a very dense medium. One example of such a medium is an infrared dark cloud, suggesting that binary inspiral is important in the creation of massive stars.

On the old question of binary formation, I had long asked observers to explore with me the connection between the very youngest binaries and their parent dense cores. After getting nowhere for years, I came into contact with Sarah Sadavoy in 2015. Sarah, then a postdoctoral researcher in Heidelberg, was enthusiastic about my idea. Even better, she had recently participated in two highly relevant observational efforts. The VANDAM project, headed by John Tobin, used the VLA to obtain a complete census of Class 0 and Class I sources in the Perseus Molecular Cloud. From the concurrent Gould Belt Survey, Sarah had 850 μm images of the cloud's dense cores. Combining these data proved to be very profitable. In our 2017 paper, we showed, using both the observations and statistical population models, that the very youngest binaries are wide pairs of Class 0 sources. These tend to lie along the axes of their dense cores. Our modeling indicates, moreover, that *all* low-mass stars, single or multiple. begin as such wide, embedded pairs.

Q: *You have also had a longstanding interest in cluster formation and evolution.*

A: True, and that interest also arose from writing the book. As Francesco and I learned about young stellar groups in the Milky Way, it struck me that open clusters, the most common type that is gravitationally bound, are unexceptional in every way. OB associations are more massive than open clusters and start out denser, yet are unbound. So too are the *less* massive T associations. What, then, is special about the formation of open clusters? The traditional answer, that their parent clouds are unusually efficient at producing stars, seems implausible. Thus, the question has bedeviled me for a long time, and continues to even today.

Aside from these particular systems, a big clue to the general origin of clusters came from my 2000 discovery with Francesco that star formation in nearby groups is accelerating. This was a purely empirical result, obtained by placing all known young stars in the HR diagram and reading off their ages. Our approach was so simple that we were shocked when the paper generated protest in the community. By now, the controversy seems to have largely died down, thanks in part to the fact that simulations of cluster formation, such as those by Enrique Vázquez-Semadeni, exhibit the same phenomenon. Regardless of the simulation details, the underlying reason is simple. Self-gravitating clouds contract, and star formation activity increases with greater gas density.

Around this same time, I began to think of using N-body simulations to recreate the earliest configuration of observed clusters, just after dissipation of their gas. In articles published in 2008 and 2010, Joe Converse and I applied this idea to the Pleiades. We did find an initial state that yielded today's cluster, when evolved over the known lifetime of the system. However, our specific answer was not nearly as interesting as something fundamental we stumbled upon along the way.

I had assumed at the outset that the Pleiades, with its central concentration of more massive stars, was a textbook example of dynamical relaxation, and would eventually experience core collapse. What our simulations revealed was that, not only is the Pleiades *not* undergoing dynamical relaxation, but that the textbooks are wrong! The Pleiades, like most bound clusters, will never have a sharp rise in central density, but will expand as a whole until it is tidally destroyed. However, we know from observations that some globular clusters *have* experienced core collapse, so what is the difference? A paper I wrote in 2014 with Ryan O'Leary and Chung-Pei Ma supplied the answer. We showed that binary heating inside clusters, a phenomenon well recognized and studied for decades, usually frustrates dynamical relaxation and inflates the cluster globally. Only in the most populous systems does this central heating fail to occur. The standard account of universal dynamical relaxation is misleading because it is based on idealized (and unrealistic) clusters of equal-mass stars.

Q: *What do you view as the outstanding unsolved problems in star formation?*

A: On most of the traditional problems of star formation, I think we have barely scratched the surface. Simulations currently dominate theoretical research. Their rich detail and the sheer volume of papers can give the impression of rapid progress on many fronts. I have qualms about current gas dynamical simulations of clouds in particular, such as the initial conditions employed (see my Perspective essays in the Newsletter issues of October 2013 and November 2016). In any event, Nature provides the ultimate check on these, and any other calculations. Moving forward, observers will continue to lead the way, providing the new facts that we theorists will then struggle to explain.

Given my misgivings regarding cloud simulations, it is hardly surprising that my list of unsolved issues is topped by the clouds' mechanical support. It is accepted that this support, for all clouds more massive than dense cores, arises from internal motion that is turbulent in nature. The observed increase of velocity dispersion with length scale broadly supports this view. By now, there are many statistical techniques for characterizing the turbulence observationally; Stella Offner and colleagues have recently enumerated 18 of them! But we still have no solid understanding, grounded in observation, of how this internal motion is generated and sustained. We are similarly ignorant of its spatial character. In recent years, the fashion has changed from describing the turbulence as wave-like to eddy-like. The second characterization seems to be inspired by simulations, rather than by observations, and in fact neither description may be apt. The motion must be dissipative to some degree, ultimately through internal shocks, many of which could be of relatively low velocity. Discerning the pattern and strength of those shocks in several real clouds, both those harboring young stars and those without them, could provide an important clue.

As I indicated, there are many outstanding problems, but I will end with one that surely is the key issue in star formation – the collapse of a dense core. The still-popular idea of inside-out collapse, which arose from the very first simulations of the late 1960s, is at least consistent with spectral energy distributions. But we have learned over many years that the latter are far from determinative. Moreover, observations to date find that the region of supersonic infall within dense cores is smaller than expected. We need to explore more systematically the differences between so-called prestellar dense cores and those already containing the very youngest stars. Armed with new facts, theorists can begin to modify their picture appropriately.

Q: *What are your current projects?*

A: I have embarked on writing a second edition of my textbook, this time with Philippe André as my coauthor. Needless to say, there have been many advances in the 15 years since the first edition came out. On the research front, I continue to assault the big unsolved issues. One is the luminosity problem, the fact that embedded stars emit far less energy than they would if they all were gathering mass from cloud infall. I have long suspected that Class I sources are generally not true protostars in this sense, and Gaspard Duchêne has joined me in probing that idea through both simulations and basic theoretical models. On the issue of dense core collapse, Aaron Lee and I are fashioning a new model for magnetized dense cores embedded within cloud filaments. Our calculation utilizes a method, originally developed with Charles Curry, that allows us to avoid the old and observationally incorrect result that all magnetized clouds are pancakes oriented perpendicular to the ambient field. Aaron and I are especially interested in clouds that are poised on the edge of collapse, in order to see why rotating ones cannot form disks in simulations (the "magnetic braking catastrophe"). Speaking of filaments, Daniele Galli and I are trying to understand and model the thin striations that surround and penetrate them. A convincing, quantitative model may help elucidate the origin of filaments themselves. With Sarah Sadavoy, I am continuing to probe the nature and origin of the youngest binaries. Our previous work indicated that these usually break apart, and we are hoping to elucidate from observational data how this breakup occurs. And finally, I am still trying to answer the nagging question of how gravitationally bound clusters arise. I am now extending the models I began with Eric Huff to include cloud mass loss driven by newly formed stars.

My Favorite Object

The triple young stellar system SR24

Manuel Fernández López

Introduction

We first began to study the triple young stellar system SR24 several years ago, while looking for possible signatures of counter-rotation between the disks of multiple protostellar systems. We had weak indications of such behavior from a protostellar system in Orion and we decided to start a bibliographical search looking for archival evidence in other regions as well. Counter-rotating objects are present in the solar system (several moons of Saturn, Jupiter and Neptune for instance). They are usually explained as external captures, with some more complicated and extreme scenarios such as Triton, the current theories explaining it as a capture of Neptune after a close encounter with a trans-Neptunian binary (see e.g., Agnor & Hamilton 2006, Nogueira et al. 2011 and references therein). However, counter-rotating protoplanetary disks are certainly an exotic scenario –given the low probability of stellar encounters– worthy of study to address some questions about the origin and fate of multiple systems and their associated planets. That is how we became *b*ound to this particular system: we found very intriguing evidence.

SR24 is located in the southwest outskirts of the Ophiuchus L1688 dark cloud (Struve & Rudkjøbing 1949), at about 120 pc from Earth (Loinard et al. 2008). It comprises a tight binary to the north (SR24Na and SR24Nb) and another young stellar object about 600 au to the south (SR24S). The near-infrared observations by Mayama et al. (2010) show two dusty disks, one surrounding the northern binary and the other associated with the southern isolated young star. We found the first evidence regarding the kinematics of the system in Correia et al. (2006): using several high-angular resolution observations at different epochs they presented the relative motion of the SR24Nb orbit around SR24Na (Figure 1). The tight northern binary follows a clockwise orbital motion. The second piece of evidence for SR24 kinematcis comes from the coronagraphic infrared observations of Mayama et al., which not only revealed the scattered light from the dusty disks, but also the faint emission from a bridge of gas physically connecting both disks and another curved arc extending south of the southern disk (Figure 2). This second arc of gas and dust was interpreted as a spiral arm associated with SR24S, and its geometry lead these authors to the interpretation that the disk was rotating counter-clockwise. Our discovery of this apparent disagreement in the sense of rotation in the disks of the SR24 system motivated us to target this source and study it further.

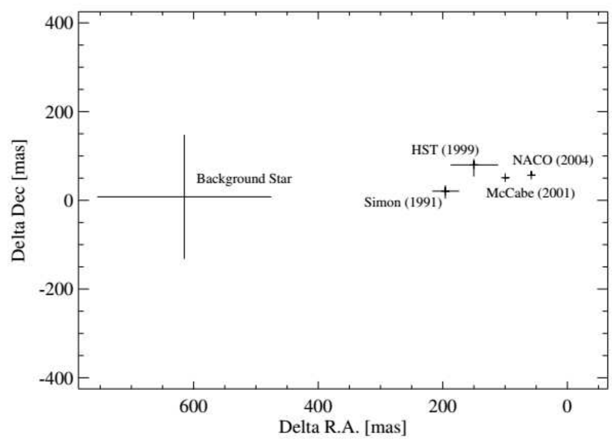

Figure 1: Astrometric measurements of SR24Nb. Position with respect to SR24Na, located at (0,0). These observations suggest that the SR24N system rotates clockwise (extracted from Correia et al. 2006).

The young stars and the disks

The SR24 system was first reported as a double star (Struve & Rudkjbing 1949; Wilking et al. 1987; Reipurth & Zinnecker 1993; Chelli et al. 1995) but Simon et al. (1995) revealed it as a triple system using near-IR lunar occultation observations. The three young stars (SR24S, SR24Na and SR24Nb) have spectral types K2, K4-M4 and K7-M5 (Cohen & Kuhi 1979; Luhman & Rieke 1999; Correia et al. 2006), masses of ~ 1.4, 0.6 and $0.3 M_{\odot}$, and ages ranging 10^6–10^7 years (Wilking et al. 2005; Correia et al. 2006). They were classified as Class II sources due to their NIR spectral index (Greene et al. 1994) and two circumstellar accretion disks were detected from NIR to mm wave-

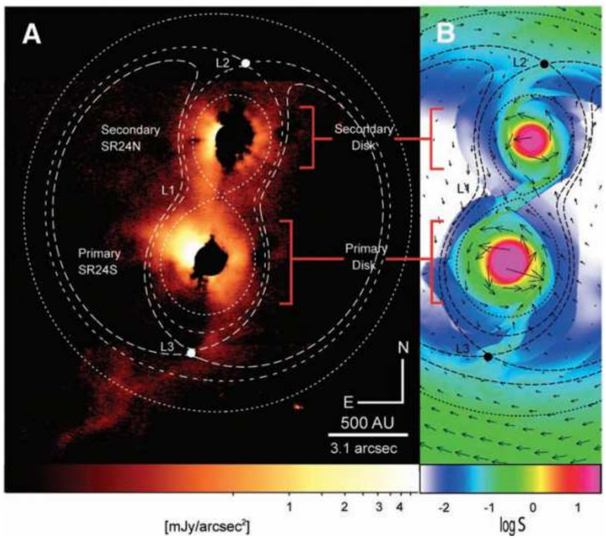

Figure 2: Left: Observed 0.1 arcsec H-band (1.6 micron) coronagraphic image of the SR24 system taken with Subaru. The inner and outer Roche lobes along with the Lagrangian points of the system are overlaid on the Subaru image (extracted from Mayama et al. 2010). The southwest spiral arm suggests a counter-clockwise rotation for the SR24S disk. Right: the simulation of a binary system with two co-rotating and co-planar disks. Note that the bridge curvature does not coincide with the SR24 bridge emission between the two disks.

lengths (e.g., Reipurth et al. 1993; Nuernberger et al. 1998). Some works have also found Hα and Paβ emission along with Li absorption, indicative of mild accretion rates 10^{-7}–10^{-8}M$_\odot$ yr^{-1} (Martín et al. 1998; Natta et al. 2006; Patience et al. 2008). Moreover, Hubble Space Telescope (HST) and H-band polarization intensity images (Potter 2003), along with a coronagraph IR image of SR24 (Mayama et al. 2010) show the emission due to the scatter of the stellar light in the circumstellar dust and gas of the SR24S and SR24N disks, with measured radii of 2.6 and 2.0 arcsec (310 and 240 au), respectively.

While both disks are equally strong emitters in the NIR, at millimeter wavelengths the disk of SR24N has very weak continuum emission (with an estimated mass of 13 M$_\oplus$) and has only been detected using sensitive ALMA observations (Andre & Montmerle 1994; Nuernberger et al. 1998; Fernández-López et al. 2017). This lead to the conclusion that the disk linked to the northern binary is devoid of cold gas and dust, and harbors warm dust just very close to the young stars, suggesting an episode of disk truncation or enhanced accretion due to binary interaction (e.g., Nuernberger et al. 1998; Stanke & Zinnecker 2000). Most recently, Schaefer et al. (2018) added two new accurate points to the orbit of the binary, constraining its period to 111 yr and other orbital parameters as well (i.e., time of periastron passage, eccentricity, semi-major axis, inclination, position angle of the line of nodes and angle between the periastron and the node; Figure 3). They strikingly showed that the binary orbit (between 35 and 60 au in size at 120 pc) encircles the position of the unresolved 1.3 mm ALMA continuum emission, suggesting that it traces the circumstellar disk associated with one or both young stellar objects. However, while the binary orbit is larger than the size of the dust emission, it is contained inside a gaseous CO(2-1) structure, which is about 144 au in size, likely associated with a rotating circumbinary disk. The kinematics and geometry of the CO disk are completely determined by assuming that it rotates in the same direction as the binary system leaving a dynamical mass of 0.8M$_\odot$ (Fernández-López et al. 2017 and Schaefer et al. 2018). This assumption solves the near/far-edge ambiguity of a projected disk, allowing to determine the direction of the angular momentum vector.

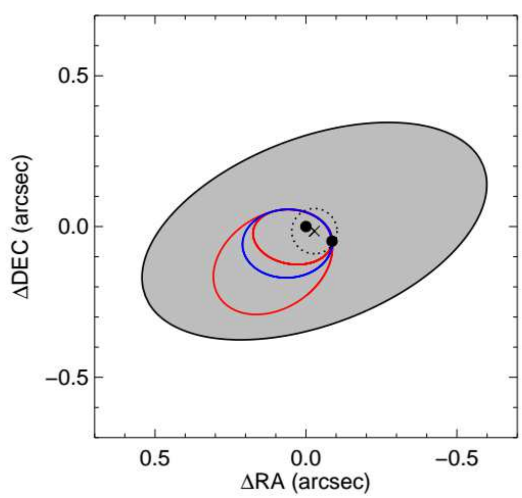

Figure 3: 2015.5 position of the two SR24N young stars (black dots, with SR24Na at the origin), the best orbit fit (blue line) and extreme possible orbits (red lines). The position and size of the ALMA 1.3 mm continuum source is marked by a cross and a dashed line. Also plot is the circumbinary CO(2-1) disk structure. Extracted from Schaefer et al. (2018).

Regarding the SR24S disk, a battery of high-angular resolution (sub)millimeter images have given insights, revealing an impressive 20-40 au wide dusty ring with an inner hole of about 30 au in radius (Andrews & Williams 2005; Patience et al. 2008; Isella et al. 2009; Andrews et al. 2010; Ricci et al. 2010; Andrews et al. 2011; Pinilla et al. 2017; see inset in Figure 4). Interestingly, the cavity is larger and shallower at 0.45 mm than at 1.3 mm, which may suggest that only smaller grains live in the inside, while larger –up to mm/cm in size – are in the ring. Alternative scenarios such as planet clearing or dust trapping at the outer edge of a dead zone were proposed by Pinilla et al. (2017), but new continuum and molecular line observations at different wavelengths are needed to find out what is causing the inner hole. A possible indication of grain growth inside the dusty ring is its very low mm-submm spectral index (2.02 ± 0.13, Pinilla et al. 2017), although optically thick emission may also help in obtaining such a low value. Molecular CO observations conducted towards SR24S showed that the gas is present in the central hole and peaks at the center (Andrews & Williams 2005; Patience et al. 2008; Isella et al. 2009; Pinilla et al. 2017; Fernández-López et al. 2017). A smaller (or non-existent) gas-cavity is expected as compared to the dust-cavity, either because of the clearing produced by small planets or because of a drop in the gas depletion inside the dead zone (see e.g. van der Marel et al. 2016). Either way, the CO traces the disk rotation very well, presenting some hints of accretion as well. This allowed to analyze the disk geometry and the direction of its angular momentum vector (Fernández-López et al. 2017), making the whole SR24 system one of the first few young (proto)stellar systems in which a full determination of the disks geometry and kinematics was possible.

A very misaligned triple system... just the usual?

The angular momentum of the SR24S circumstellar disk is misaligned by about 108° with respect to that of the CO circumbinary structure associated with the SR24N binary. Having two misaligned disks is not uncommon; there is a growing number of evidence about misaligned disks in multiple systems: optical polarimetric observations (e.g., Monin et al. 2006), misaligned outflows (e.g., Lee et al. 2016), direct imaging of disks (Stapelfeldt et al. 1998; Kang et al. 2008; Ratzka et al. 2009; Roccatagliata et al. 2011) and high-angular resolution of disk kinematics (Jensen & Akeson 2014; Salyk et al. 2014; Williams et al. 2014). Even in the Solar System there are many examples of planets and moons presenting inclined axes or even retrograde motions separating them from the main *Solar* stream –as mentioned earlier. While many of the retrograde moons in the solar system are thought to be due to capture, the low probability of such happening between young stellar objects (less than 10^{-5} in Ophiuchus) suggests other mechanisms as the cause for the disk misalignment in SR24. These are turbulence in the collapse of the original cloud; an accretion kick from an external reservoir onto one of the disks; the outcome of a close passage between the originally bound members of a multiple system. In the case of SR24, there is no final evidence to exclude any of these possibilities, although there is some suspicious evidence pointing at a possible episode of accretion from a gas pocket onto SR24N. The bulk of this extended gas pocket (seen in CO with SMA observations as a quite extended source, Andrews et al. 2005; Fernández-López et al. 2017) peaks ~ 350 au north of the SR24N position and it is connected with the emission from the SR24N disk. Interestingly, the CO emission from the gas pocket is stronger than the emission from the SR24S disk in the lower-angular resolution images from SMA. Would it be infalling onto the SR24N disk, it may be enough to perturb its orbital parameters.

All these systems presenting misaligned disks show that this may be a common state for young (proto)stellar systems. Considering that most stars are formed as multiples, it is likely that at some point strong gravitational interactions may induce tilts, warps and misalignment in disks.

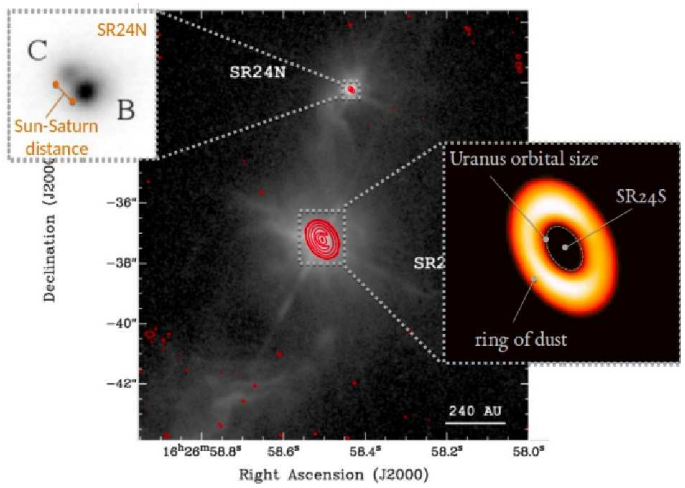

Figure 4: Composite of the SR24 system seen by HST (grey; F606W filter) and ALMA 1.3mm continuum (red contours; Fernández-López et al. 2017). Insets: NIR Fe[II] emission of the SR24N binary system taken with NACO/VLT (Correia et al. 2006) and ALMA 1.3mm continuum of the SR24S transitional disk (Pinilla et al. 2017).

Arcs, tails and bridges

Hints of gravitational interactions among the members of SR24 are the extended emission in form of arcs or tails, joining SR24S and SR24N, or *escaping* from them. In the PhD thesis work from Potter (2003) there is a complete relation of the structures produced by light scattered in the dust and gas observed with the HST (Figures 4 and 5). The most prominent features are (i) a bridge joining the SR24N and SR24S disks –which appears curved and following two distinct paths–, and (ii) a prominent arc south of SR24S, interpreted as a spiral arm by Mayama et al. (2010). From numerical simulations it is well established that binary systems have bridges of material like the one observed in SR24. However, in this case the bridge has a curvature that models including two disks with the same sense of rotation cannot reproduce, probably indicating a more complicated kinematic behavior of the SR24 members and again supporting the finding of a highly misaligned system. As for the southern filamentary structure, it is reminiscent of a disk's spiral arm, but it extends south/southeast for about 500 to 600 au, much further away than the disk size itself. The southern arm ends in a diffuse but still structured fan-shape tail (Potter 2003) maybe suggesting the unwrapping of the spiral arm after a passage with the companion or another dynamical development involving the outer envelope of the young star.

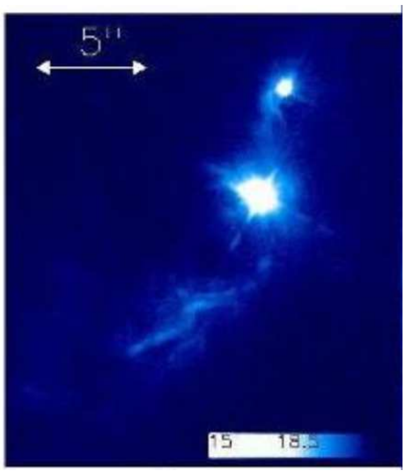

Figure 5: Subarcsecond (0.75 arcsec) HST WFPC2 image of SR24 in the F606W filter. Large scale filamentary structure may indicate ongoing dynamical interactions between the members of the triple. Extracted from Ubach (2009).

The SR24 neighborhood

About 6' east from the triple system ($\sim$ 0.2 pc at the distance of the Ophiuchus clouds), optical Hα and [SII] observations revealed several Herbig-Haro objects (usually referred as HH objects; see Figure 6). In particular, the original HH224 (Wilking et al. 1987; Reipurth & Zinnecker 1993) has been progressively resolved and extended –using H_2 and Spitzer images as well– into an more or less aligned chain of objects: HH224S, HH224N, HH224NW1, HH224NW2, which span SE-NW for about 0.3 pc (Wilking et al. 1997; Gómez et al. 1998; Reipurth 1999; Phelps & Barsony 2004; Khanzadyan et al. 2004). With no clear driving source identified at this moment, the possibility that these HH objects are emanating from SR24S as originally proposed by Reipurth & Zinnecker (1993), is weakened because it is not aligned with them (e.g., Phelps & Barsony et al. 2004; Khanzadyan et al. 2004). Other candidates exist: (i) GY193 is a near-infrared source with no significant color excess, located in between the middle of HH224NW2; (ii) the Class II source BKLT J162722-244807 lies at the tip of the *extended green object* EGO26, which spatially coincides with HH224S and has been taken as a wide-cavity outflow by Zhang et al. (2009). No other source has been proposed as a serious candidate for being the driving source of these HH objects and it is possible that more than one outflow is confused in the images (e.g., Phelps & Barsony et al. 2004; Zhang et al. 2009). Moreover, the curved nature of some of the HH objects like HH224NW2 –which is concave as seen from SR24– may suggest an ejection from SR24, while the discovery of new H_2 shocked gas closer to the system (objects f03-01 in Khanzadyan et al. 2004) do not allow to rule out the possibility of SR24 launching other outflows in the past.

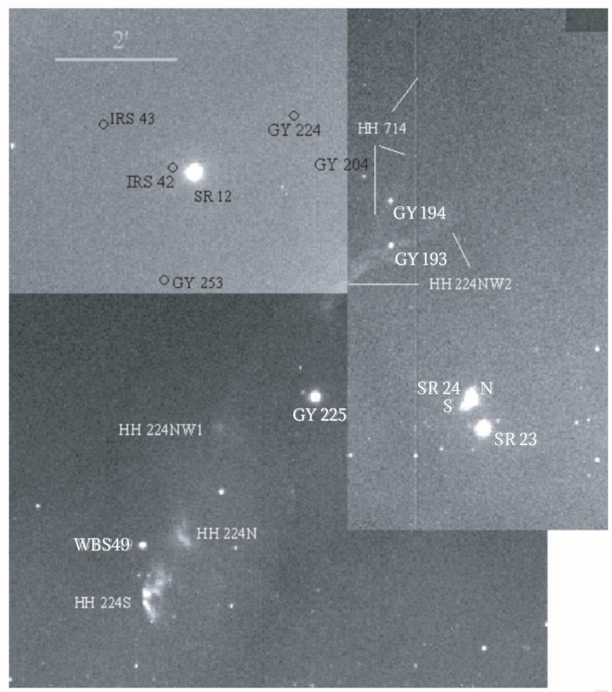

Figure 6: [SII] mosaic image toward the HH224 region. Several young stellar objects are indicated along with the most prominent HH objects. Extracted from Phelps & Barsony (2004).

Provided that the SR24 triple system shows signposts of gravitational interactions, we may expect a different picture of its jets and outflows from that of a *well-behaved* bipolar ejection. If the interactions are strong, we may be looking for some loose bullets or HH objects that may not be apparently quite aligned with each other –moreover if they are old and far away from their origin. If this is the case, perhaps the HH objects from the surroundings of SR24 may fit in with this scenario, which may not be so different from the usual star-formation scenario, if we take into account that multiples are the usual way of forming stars.

As a prospect for future research in the SR24 system, there could be some interesting steps forward. It is needed to carry out new deeper optical and NIR H_2 observations to trace the HH structures and identify their driving sources in the surroundings of SR24, barely detected (or yet unseen) in previous experiments. Maybe even integral field observations can aid in the identification of the jets (if any remains) of SR24S. Also, further investigation of the pocket of gas north of SR24N will determine whether it is infalling onto this binary. At smaller scales, a new high-angular resolution epoch on the SR24N binary will put the final constrain to determine the orbit of the system and a thorough study of the asymmetry of the SR24S ring brightness will allow to understand its nature and implications. Additionally, we still do not know what is causing the central cavity of SR24S. Confirming that the clearing is produced by a planetary system would be a hallmark in planet formation in a member of a multiple systems with signs of gravitational interactions, but we still need to figure out how to bring this piece of evidence closer.

References: Agnor, C. B., & Hamilton, D. P. 2006, Nature, 441, 192

Andre, P., & Montmerle, T. 1994, ApJ, 420, 837

Andrews, S. M., & Williams, J. P. 2005, ApJL, 619, L175

Andrews, S. M., Wilner, D. J., Espaillat, C., et al. 2011, ApJ, 732, 42

Andrews, S. M., Wilner, D. J., Hughes, A. M., Qi, C., & Dullemond, C. P. 2010, ApJ, 723, 1241

Correia, S., Zinnecker, H., Ratzka, T., & Sterzik, M. F. 2006, A&A, 459, 909

Cohen, M., & Kuhi, L. V. 1979, ApJS, 41, 743

Chelli, A., Cruz-Gonzalez, I., Zinnecker, H., Carrasco, L., & Perrier, C. 1988, A&A, 207, 46

Fernández-López, M., Zapata, L., Gabbasov, R. 2017, ApJ, 845, 10

Gómez, M., Whitney, B. A., & Wood, K. 1998, AJ, 115, 2018

Greene, T. P., Wilking, B. A., P., Young, E. T., & Lada, C. J. 1994, Andre ,ApJ, 434, 614

Isella, A., Carpenter, J. M., & Sargent, A. I. 2009, ApJ, 701, 260

Jensen, E. L. N., & Akeson, R. 2014, Natur, 511, 567

Khanzadyan, T., Gredel, R., Smith, M. D., & Stanke, T. 2004, A&A, 426, 171

Lee, K. I., Dunham, M. M., Myers, P. C., et al. 2016, ApJL, 820, L2

Loinard, L., Torres, R. M., Mioduszewski, A. J., & Rodrguez, L. F. 2008, ApJL, 675, L29

Luhman, K. L., & Rieke, G. H. 1999, ApJ, 525, 440

Martín, E. L., Montmerle, T., Gregorio-Hetem, J., & Casanova, S. 1998, MNRAS, 300, 733

Mayama, S., Tamura, M., Hanawa, T., et al. 2010, Sci, 327, 306

Monin, J.-L., Mnard, F., & Peretto, N. 2006, A&A, 446, 201

Natta, A., Testi, L., & Randich, S. 2006, A&A, 452, 245

Nogueira, E., Brasser, R., Gomes, R. 2011, Icar, 214, 113

Nuernberger, D., Brandner, W., Yorke, H. W., & Zinnecker, H. 1998, A&A, 330, 549

Patience, J., Akeson, R. L., & Jensen, E. L. N. 2008, ApJ, 677, 616

Phelps, R. L., & Barsony, M. 2004, AJ, 127, 420

Pinilla, P., Prez, L. M., Andrews, S., et al. 2017, ApJ, 839, 99

Potter, D. E. 2003, PhD thesis, Univ. Hawaii

Reipurth, B., & Zinnecker, H. 1993, A&A, 278, 81

Reipurth, B., Chini, R., Krugel, E., Keysa, E., & Sievers, A. 1993, A&A, 273, 221

Reipurth, B. 1999, A General Catalog of Herbig-Haro Objects (2d ed.; Boulder: Center Astrophys. & Space Astron.)

Ratzka, T., Schegerer, A. A., Leinert, C., et al. 2009, A&A, 502, 623

Ricci, L., Testi, L., Natta, A., & Brooks, K. J. 2010, A&A, 521, A66

Roccatagliata, V., Ratzka, T., Henning, T., et al. 2011, A&A, 534, A33

Salyk, C., Pontoppidan, K., Corder, S., et al. 2014, ApJ, 792, 68

Schaefer, G. H., Prato, L., Simon, M. 2018, AJ, 155, 3

Stanke, T., & Zinnecker, H. 2000, IAUS, 200, 38

Stapelfeldt, K. R., Krist, J. E., Ménard, F., et al. 1998, ApJL, 502, L65

Simon, M., Ghez, A., Leinert, Ch., et al. 1995, ApJ, 443, 625

Struve, O., & Rudkjøbing, M. 1949, ApJ, 109, 92

Ubach, C. C. 2009, Master's Report, The University of Arizona

van der Marel, N., van Dishoeck, E. F., Bruderer, S., Andrews, S. M., Pontoppidan, K. M., Herczeg, G. J., van Kempen, T., & Miotello, A. 2016, A&A, 585, 58

Wilking, B. A., Schwartz, R. D., & Blackwell, J. H. 1987, AJ, 94, 106

Wilking, B. A., Schwartz, R. D., Fanetti, T. M., & Friel, E. D. 1997, PASP, 109, 549

Wilking, B. A., Meyer M. R., Robinson, J. G., Greene, T. P. 2005, ApJ, 130, 1733

Williams, J. P., Mann, R. K., Di Francesco, J., et al. 2014, ApJ, 796, 120

Zhang, M., & Wang, H. 2009, AJ, 138, 1830

Abstracts of recently accepted papers

The formation of Jupiter by hybrid pebble-planetesimal accretion

Yann Alibert[1], Julia Venturini[2], Ravit Helled[2], Sareh Ataiee[1], Remo Burn[1], Luc Senecal[1], Willy Benz[1], Lucio Mayer[2], Christoph Mordasini[1], Sascha P. Quanz[3], Maria Schönbächler[4]

[1] Physikalisches Institut & Center for Space and Habitability, Universität Bern, Gesellschaftsstrasse 6, 3012 Bern, Switzerland; [2] Institut for Computational Sciences, Universität Zürich, Winterthurstrasse 190, 8057 Zürich, Switzerland; [3] Institute for Particle Physics and Astrophysics, ETH Zürich, Wolfgang-Pauli-Strasse 27, 8093 Zürich, Switzerland; [4] Institute of Geochemistry and Petrology, ETH Zürich, Clausiusstrasse 25, 8092 Zürich, Switzerland

E-mail contact: julia.venturini *at* issibern.ch

The standard model for giant planet formation is based on the accretion of solids by a growing planetary embryo, followed by rapid gas accretion once the planet exceeds a so-called critical mass. The dominant size of the accreted solids (cm-size particles named pebbles or km to hundred km-size bodies named planetesimals) is, however, unknown. Recently, high-precision measurements of isotopes in meteorites provided evidence for the existence of two reservoirs in the early Solar System. These reservoirs remained separated from ∼1 until ∼3 Myr after the beginning of the Solar System's formation. This separation is interpreted as resulting from Jupiter growing and becoming a barrier for material transport. In this framework, Jupiter reached ∼20 Earth masses within ∼1 Myr and slowly grew to ∼50 Earth masses in the subsequent 2 Myr before reaching its present-day mass. The evidence that Jupiter slowed down its growth after reaching 20 Earth masses for at least 2 Myr is puzzling because a planet of this mass is expected to trigger fast runaway gas accretion. Here, we use theoretical models to describe the conditions allowing for such a slow accretion and show that Jupiter grew in three distinct phases. First, rapid pebble accretion brought the major part of Jupiter's core mass. Second, slow planetesimal accretion provided the energy required to hinder runaway gas accretion during 2 Myr. Third, runaway gas accretion proceeded. Both pebbles and planetesimals therefore have an important role in Jupiter's formation.

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The Dynamical Evolution of Multiple Systems of Trapezium Type

Christine Allen[1], Alex Ruelas-Mayorga[1], Leonardo J. Sánchez[1], Rafael Costero[1]

[1] Instituto de Astronomía, Universidad Nacional Autónoma de México, Cd. Universitaria, México, D.F. 04510, México

E-mail contact: chris *at* astro.unam.mx

We have selected archival observational data for several O and B trapezia in the Milky Way. For each of the main components of the trapezia we obtained transverse velocities from the historical separation data. With this information, and with the stellar masses of the main components, we studied the dynamical evolution of ensembles of multiple systems mimicking each one of the trapezia. For this purpose we conducted numerical N–body integrations using the best available values for the masses, the observed positions and **transverse** velocities, randomly generated radial velocities, and random line-of-sight (z) positions for all components. Random perturbations were assigned to the observed quantities, compatible with the observational errors. A large fraction of the simulated systems (**between 70 and 90 percent**) turned out to be unbound. The properties of the evolving systems are studied at different values of the evolution time. We find that the dynamical lifetimes of both the bound and unbound seems to be quite short, of less than 10 000 yr for the unbound systems, and of 10 000 to 20 000 yr for the bound systems. The end result of the simulations is usually a binary **with semiaxes of a few hundred AU** sometimes a triple of hierarchical on non-hierarchical type. Non-hierarchical triples formed during the integrations (which are dynamically unstable) were found to have much longer lifetimes, of 250 000 to 500 000 yr. The frequency distributions of the major semi-axes and eccentricities of the resulting binaries are discussed and compared with observational properties of binary systems

from the literature.

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Search for High-Mass Protostellar Objects in Cold IRAS Sources

Y. Ao[1,2], J. Yang[1], K. Tatematsu[2], C. Henkel[3,4], K. Sunada[5] and Q. Nguyen-Luong[2,6]

[1] Purple Mountain Observatory & Key Laboratory for Radio Astronomy, Chinese Academy of Sciences, 8 Yuanhua Road, Nanjing 210034, China; [2] National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan; [3] MPIfR, Auf dem Hügel 69, 53121 Bonn, Germany; [4] Astron. Dept., King Abdulaziz Univ., P.O. Box 80203, Jeddah 21589, Saudi Arabia; [5] Mizusawa VLBI Observatory, NAOJ, 2-12 Hoshi-ga-oka, Mizusawa-ku, Oshu-shi, Iwate 023-0861, Japan; [6] Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, Yuseong-gu, Daejeon 34055, Korea

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

We present the results of CS $J = 2$–1 mapping observations towards 39 massive star-forming regions selected from the previous CO line survey of cold IRAS sources with high-velocity CO flows along the Galactic plane (Yang et al. 2002). All sources are detected in CS $J = 2$–1 showing the existence of CS clumps around the IRAS sources. However, one-third of the sources are not deeply embedded in the dense clumps by comparison of the central powering IRAS sources and the morphologies of CS clumps. Physical parameters of the dense molecular clumps are presented. We have identified 12 high-mass protostellar object (HMPO) candidates by checking the association between the dense cores and the IRAS sources, the detection of water maser, and the radio properties towards the IRAS sources. We find that the HMPO sources are characterized by low FIR luminosity to virial mass ratios since they are in very early evolutionary stages when the massive protostars have not reached their full luminosities, which are typical for zero-age main sequence stars. Large turbulent motion in the HMPO sources may be largely due to the large kinetic energy ejected by the central protostars formed in the dense clumps. However, alternative means or undetected outflows may also be responsible for the turbulence in the clumps.

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Characterizing the properties of nearby molecular filaments observed with *Herschel*

Doris Arzoumanian[1,2], Philippe André[2], Vera Könyves[2,3], Pedro Palmeirim[4], Arabindo Roy[2,5], Nicola Schneider[5,6], Milena Benedettini[7], Pierre Didelon[2], James Di Francesco[8], Jason Kirk[3], and Bilal Ladjelate[2,9]

[1] Department of Physics, Graduate School of Science, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8602, Japan; [2] Laboratoire AIM, CEA/DRF–CNRS–Université Paris Diderot, IRFU/Département d'Astrophysique, C.E. Saclay, Orme des Merisiers, 91191 Gif-sur-Yvette, France; [3] Jeremiah Horrocks Institute, University of Central Lancashire, Preston PR1 2HE, UK; [4] Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto, CAUP, Rua das Estrelas, PT4150-762 Porto, Portugal; [5] Université de Bordeaux, LAB, UMR 5804, 33270 Floirac, France; [6] I. Physik. Institut, University of Cologne, Zülpicher Str. 77, 50937 Koeln, Germany; [7] INAF-Istituto di Astrofisica e Planetologia Spaziali, via Fosso del Cavaliere 100, 00133 Roma, Italy; [8] National Research Council Canada, 5071 West Saanich Road, Victoria, BC V9E 2E7, Canada; [9] Institut de RadioAstronomie Millimétrique (IRAM), Granada, Spain

E-mail contact: doris.arzoumanian *at* nagoya-u.jp; philippe.andre *at* cea.fr

Context. Molecular filaments have received special attention recently, thanks to new observational results on their properties. In particular, our early analysis of filament properties from *Herschel* imaging data in three nearby molecular clouds revealed a narrow distribution of median inner widths centered at a characteristic value of about 0.1 pc.
Aims. Here, we extend and complement our initial study with a detailed analysis of the filamentary structures identified with *Herschel* in eight nearby molecular clouds (at distances <500 pc). Our main goal is to establish statistical distributions of median properties averaged along the filament crests and to compare the results with our earlier work based on a smaller number of filaments.
Methods. We use the column density (N_{H_2}) maps derived from *Herschel* data and the DisPerSE algorithm to trace a network of individual filaments in each cloud. We analyze the density structure along and across the main filament

axes in detail. We build synthetic maps of filamentary clouds to assess the completeness limit of our extracted filament sample and validate our measurements of the filament properties. These tests also help us to select the best choice of parameters to be used for tracing filaments with DisPerSE and fitting their radial column density profiles.

Results. Our analysis yields an extended sample of 1310 filamentary structures and a selected sample of 599 filaments with aspect ratios larger than 3 and column density contrasts larger than 0.3. We show that our selected sample of filaments is more than 95 % complete for column density contrasts larger than 1, with only ∼ 5 % of spurious detections. On average, more than 15 % of the total gas mass in the clouds, and more than 80 % of the dense gas mass (at $N_{H_2} > 7 \times 10^{21}\,\mathrm{cm}^{-2}$), is found to be in the form of filaments, respectively. Analysis of the radial column density profiles of the 599 filaments in the selected sample indicates a narrow distribution of crest-averaged inner widths, with a median value of 0.10 pc and an interquartile range of 0.07 pc. In contrast, the extracted filaments span wide ranges in length, central column density, column density contrast, and mass per unit length. The characteristic filament width is well resolved by *Herschel* observations, and a median value of ∼0.1 pc is consistently found using three distinct estimates based on (1) a direct measurement of the width at half power after background subtraction, as well as (2) Gaussian and (3) Plummer fits. The existence of a characteristic filament width is further supported by the presence of a tight correlation between mass per unit length and central column density for the observed filaments.

Conclusions. Our detailed analysis of a large filament sample confirms our earlier result that nearby molecular filaments share a common mean inner width of ∼0.1 pc, with typical variations along and on either side of the filament crests of about ±0.06 pc around the mean value. This observational result sets strong constraints on possible models for the formation and evolution of filaments in molecular clouds. It also provides important hints on the initial conditions of star formation.

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ALMA observations of polarized emission toward the CW Tau and DG Tau protoplanetary disks: constraints on dust grain growth and settling

F. Bacciotti[1], J.M. Girart[2,3], M. Padovani[1], L. Podio[1], R. Paladino[4], L. Testi[5,1], E. Bianchi[6], D. Galli[1], C. Codella[1], D. Coffey[7,8], C. Favre[1] and D. Fedele[1]

[1] Istituto Nazionale di Astrofisica - Osservatorio Astrofisico di Arcetri, Largo E. Fermi, 5, I-50125 Firenze, Italy; [2] Institut de Ciències de l'Espai (ICE, CSIC), Can Magrans, s/n, E-08193 Cerdanyola del Vallés, Catalonia; [3] Institut d'Estudis Espacials de Catalunya (IEEC), E-08034, Barcelona, Catalonia; [4] Istituto Nazionale di Astrofisica - Istituto di Radioastronomia Via P. Gobetti, 101 40129 Bologna, Italy; [5] European Southern Observatory, Karl-Schwarzschild-Strasse 2, 85748 Garching bei München, Germany; [6] Institut de Planetologie et d'Astrophysique de Grenoble (IPAG) Université Grenoble Alpes, CS 40700, 38058 Grenoble Cédex 9, France; [7] School of Physics, University College Dublin, Belfield, Dublin 4, Ireland; [8] School of Cosmic Physics, The Dublin Institute for Advanced Studies, Dublin 2, Ireland

E-mail contact: fran *at* arcetri.astro.it

We present polarimetric data of CW Tau and DG Tau, two well-known Class II disk/jet systems, obtained with the Atacama Large Millimeter/submillimeter Array at 870 μm and 0."2 average resolution. In CW Tau, the total and polarized emission are both smooth and symmetric, with polarization angles almost parallel to the minor axis of the projected disk. In contrast, DG Tau displays a structured polarized emission, with an elongated brighter region in the disk's near side and a belt-like feature beyond about 0."3 from the source. At the same time the total intensity is spatially smooth, with no features. The polarization pattern, almost parallel to the minor axis in the inner region, becomes azimuthal in the outer belt, possibly because of a drop in optical depth. The polarization fraction has average values of 1.2% in CW Tau and 0.4% in DG Tau. Our results are consistent with polarization from self-scattering of the dust thermal emission. Under this hypothesis, the maximum size of the grains contributing to polarization is in the range 100 - 150 μm for CW Tau and 50 - 70 μm for DG Tau. The polarization maps combined with dust opacity estimates indicate that these grains are distributed in a geometrically thin layer in CW Tau, representing a settling in the disk midplane. Meanwhile, such settling is not yet apparent for DG Tau. These results advocate polarization studies as a fundamental complement to total emission observations, in investigations of the structure and the evolution of protoplanetary disks.

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Shadows and asymmetries in the T Tauri disk HD 143006: Evidence for a misaligned inner disk

M. Benisty[1,2], A. Juhász[3], S. Facchini[4], P. Pinilla[5], J. de Boer[6], L.M. Pérez[7], M. Keppler[8], G. Muro-Arena[9], M. Villenave[10,2], S. Andrews[11], C. Dominik[9], C.P. Dullemond[12], A. Gallenne[10], A. Garufi[13], C. Ginski[6,9], and A. Isella[14]

[1] Unidad Mixta Internacional Franco-Chilena de Astronomía (CNRS, UMI 3386), Departamento de Astronomía, Universidad de Chile, Camino El Observatorio 1515, Las Condes, Santiago, Chile; [2] Univ. Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France; [3] Institute of Astronomy, Madingley Road, Cambridge CB3 OHA, UK; [4] Max-Planck-Institut für Extraterrestrische Physik, Giessenbachstrasse 1, 85748 Garching, Germany; [5] Department of Astronomy/Steward Observatory, The University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721, USA; [6] Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA Leiden, The Netherlands; [7] Universidad de Chile, Departamento de Astronoma, Camino El Observatorio 1515, Las Condes, Santiago, Chile; [8] Max Planck Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany; [9] Anton Pannekoek Institute for Astronomy, University of Amsterdam, Science Park 904,1098XH Amsterdam, The Netherlands; [10] European Southern Observatory, Alonso de Córdova 3107, Vitacura, Casilla 19001, Santiago, Chile; [11] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138; [12] Zentrum für Astronomie, Heidelberg University, Albert-Ueberle-Strasse 2, D-69120 Heidelberg, Germany; [13] INAF, Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, I-50125 Firenze, Italy; [14] Department of Physics and Astronomy, Rice University, 6100 Main Street, Houston, TX, 77005, USA

E-mail contact: Myriam.Benisty *at* univ-grenoble-alpes.fr

While planet formation is thought to occur early in the history of a protoplanetary disk, the presence of planets embedded in disks, or of other processes driving disk evolution, might be traced from their imprints on the disk structure. We observed the T Tauri star HD 143006, located in the 5–11 Myr-old Upper Sco region, in polarized scattered light with VLT/SPHERE at near-infrared wavelengths, reaching an angular resolution of $\sim 0\farcs037$ ($\sim$6 au). We obtained two datasets, one with a 145 mas diameter coronagraph, and the other without, enabling us to probe the disk structure down to an angular separation of $\sim 0\farcs06$ ($\sim$10 au). In our observations, the disk of HD 143006 is clearly resolved up to $\sim 0\farcs5$ and shows a clear large-scale asymmetry with the eastern side brighter than the western side. We detect a number of additional features, including two gaps and a ring. The ring shows an overbrightness at a position angle (PA) of $\sim 140°$, extending over a range in position angle of $\sim 60°$, and two narrow dark regions. The two narrow dark lanes and the overall large-scale asymmetry are indicative of shadowing effects, likely due to a misaligned inner disk. We demonstrate the remarkable resemblance between the scattered light image of HD 143006 and a model prediction of a warped disk due to an inclined binary companion. The warped disk model, based on the hydrodynamic simulations combined with 3D radiative transfer calculations, reproduces all major morphological features. However, it does not account for the observed overbrightness at PA$\sim$140°. Shadows have been detected in several protoplanetary disks, suggesting that misalignment in disks is not uncommon. However, the origin of the misalignment is not clear. As-yet-undetected stellar or massive planetary companions could be responsible for them, and naturally account for the presence of depleted inner cavities.

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A Multiwavelength Look at Galactic Massive Star-forming Regions

Breanna A. Binder[1] and Matthew S. Povich[1]

[1] Department of Physics and Astronomy, California State Polytechnic University, 3801 West Temple Ave, Pomona, CA 91768, USA

E-mail contact: mspovich *at* cpp.edu

We present a multiwavelength study of 28 Galactic massive star-forming HII regions. For 17 of these regions, we present new distance measurements based on Gaia DR2 parallaxes. By fitting a multicomponent dust, blackbody, and power-law continuum model to the 3.6 μm through 10 mm spectral energy distributions, we find that $\sim$34% of Lyman continuum photons emitted by massive stars are absorbed by dust before contributing to the ionization of HII regions, while $\sim$68% of the stellar bolometric luminosity is absorbed and reprocessed by dust in the HII regions and surrounding photodissociation regions. The most luminous, infrared-bright regions that fully sample the upper stellar initial mass function (ionizing photon rates $N_C \geq 10^{50}$ s^{-1} and dust-processed $L_{\rm TIR} \geq 10^{6.8}$ L$_\odot$ have on average higher percentages of absorbed Lyman continuum photons (∼51%) and reprocessed starlight (∼82%) compared to less luminous regions. Luminous HII regions show lower average PAH fractions than less luminous regions, implying that the strong radiation fields from early-type massive stars are efficient at destroying PAH molecules. On average, the monochromatic luminosities at 8, 24, and 70 μm combined carry 94% of the dust-reprocessed $L_{\rm TIR}$. L_{70} captures ∼52% of $L_{\rm TIR}$, and is therefore the preferred choice to infer the bolometric luminosity of dusty star-forming regions. We calibrate SFRs based on L_{24} and L_{70} against the Lyman continuum photon rates of the massive stars in each region. Standard extragalactic calibrations of monochromatic SFRs based on population synthesis models are generally consistent with our values.

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The extraordinary outburst in the massive protostellar system NGC 6334I-MM1: Flaring of the water masers in a north-south bipolar outflow driven by MM1B

C. L. Brogan[1], T. R. Hunter[1], C. J. Cyganowski[2], J. O. Chibueze[3,4,5], R. K. Friesen[1], T. Hirota[6], G. C. MacLeod[7,8], B. A. McGuire[1] and A. M. Sobolev[9]

[1] National Radio Astronomy Observatory, 520 Edgemont Rd, Charlottesville, VA 22903, USA; [2] SUPA, School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews KY16 9SS, UK; [3] Department of Physics and Astronomy, University of Nigeria, Carver Building, 1 University Road, Nsukka, 410001, Nigeria; [4] SKA South Africa, 3rd Floor, The Park, Park Road, Pinelands, Cape Town, 7405, South Africa; [5] Centre for Space Research, Physics Department, North-West University, Potchefstroom, 2520, South Africa; [6] National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan; [7] Hartebeesthoek Radio Astronomy Observatory, PO Box 443, Krugersdorp 1740, South Africa; [8] The University of Western Ontario, 1151 Richmond Street, London, ON N6A 3K7, Canada; [9] Astronomical Observatory, Institute for Natural Sciences and Mathematics, Ural Federal University, Ekaterinburg, 620000, Russian Federation

E-mail contact: cbrogan *at* nrao.edu

We compare multi-epoch sub-arcsecond VLA imaging of the 22 GHz water masers toward the massive protocluster NGC 6334I observed before and after the recent outburst of MM1B in (sub)millimeter continuum. Since the outburst, the water maser emission toward MM1 has substantially weakened. Simultaneously, the strong water masers associated with the synchrotron continuum point source CM2 have flared by a mean factor of 6.5 (to 4.2 kJy) with highly-blueshifted features (up to 70 km s^{-1} from LSR) becoming more prominent. The strongest flaring water masers reside 3000 au north of MM1B and form a remarkable bow shock pattern whose vertex coincides with CM2 and tail points back to MM1B. Excited OH masers trace a secondary bow shock located ∼120 au downstream. ALMA images of CS (6-5) reveal a highly-collimated north-south structure encompassing the flaring masers to the north and the non-flaring masers to the south seen in projection toward the MM3-UCHII region. Proper motions of the southern water masers over 5.3 years indicate a bulk projected motion of 117 km s^{-1} southward from MM1B with a dynamical time of 170 yr. We conclude that CM2, the water masers, and many of the excited OH masers trace the interaction of the high velocity bipolar outflow from MM1B with ambient molecular gas. The previously-excavated outflow cavity has apparently allowed the radiative energy of the current outburst to propagate freely until terminating at the northern bow shock where it has strengthened the masers. Additionally, water masers have been detected toward MM7 for the first time, and a highly-collimated outflow from MM4 has been detected in CS (6-5).

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Evidence for a massive dust-trapping vortex connected to spirals: a multi-wavelength analysis of the HD 135344B protoplanetary disk

P. Cazzoletti[1], E.F. van Dishoeck[1,2], P. Pinilla[3], M. Tazzari[4], S. Facchini[1], N. van der Marel[5], M. Benisty[6,7], A. Garufi[8], and L.M. Pérez[9]

[1] Max-Planck-Institut für Extraterrestrische Physik, Gießenbachstraße, 85741 Garching bei München, Germany; [2]

Leiden Observatory, Leiden University, Niels Bohrweg 2, 2333 CA Leiden, The Netherlands; [3] Department of Astronomy/Steward Observatory, The University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721, USA; [4] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK; [5] Herzberg Astronomy & Astrophysics Programs, National Research Council of Canada, 5071 West Saanich Road, Victoria BC V9E 2E7, Canada; [6] Unidad Mixta Internacional Franco-Chilena de Astronomía (CNRS, UMI 3386), Departamento de Astronomía, Universidad de Chile, Camino El Observatorio 1515, Las Condes, Santiago, Chile; [7] Univ. Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France; [8] INAF, Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, I-50125 Firenze, Italy; [9] Departamento de Astronomía, Universidad de Chile, Camino El Observatorio 1515, Las Condes, Santiago, Chile

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

Spiral arms, rings and large scale asymmetries are structures observed in high resolution observations of protoplanetary disks, and it appears that some of the disks showing spiral arms in scattered light also show asymmetries in millimeter-sized dust. HD 135344B is one of these disks. Planets are invoked as the origin of these structures, but no planet has been observed so far. We investigate the nature of the asymmetric structure in the HD 135344B disk in order to understand the origin of the spirals and of the asymmetry seen in this disk. Ultimately, we aim at understanding whether or not one or more planets are needed to explain such structures. We present new ALMA sub-0.″1 resolution observations in Band 3 and 4. The high spatial resolution allows us to characterize the mm-dust morphology of the disk. The low optical depth of continuum emission probes the bulk of the dust in vortex. Moreover, we combine the new observations with archival data to perform a multi-wavelength analysis and to obtain information about the dust distribution and properties inside the asymmetry. We resolve the asymmetric disk into a symmetric ring + asymmetric crescent, and observe that: (1) the spectral index strongly decreases at the center of the vortex, consistent with the presence of large grains; (2) for the first time, an azimuthal shift of the peak of the vortex with wavelength is observed; (3) the azimuthal width of the vortex decreases at longer wavelengths, as expected for dust traps. These features allow to confirm the nature of the asymmetry as a vortex. Finally a lower limit to the total mass of the vortex is 0.3 $M_{\rm Jupiter}$. Considering the uncertainties involved in this estimate, it is possible that the actual mass of the vortex is higher and possibly within the required values ($\sim$4 $M_{\rm Jupiter}$) to launch spiral arms similar to those observed in scattered light.

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The Ophiuchus DIsc Survey Employing ALMA (ODISEA) - I : project description and continuum images at 28 au resolution

Lucas A. Cieza[1,2], Dary Ruíz-Rodríguez[3], Antonio Hales[4,5], Simon Casassus[2,6], Sebastian Pérez[2,6], Camilo Gonzalez-Ruilova[2,6], Hector Cánovas[7], Jonathan P. Williams[8], Alice Zurlo[1,2], Megan Ansdell[9], Henning Avenhaus[10], Amelia Bayo[11,12], Gesa H.-M. Bertrang[2,6,13], Valentin Christiaens[2,6], William Dent[4], Gabriel Ferrero[14], Roberto Gamen[14], Johan Olofsson[11,12], Santiago Orcajo[14], Karla Peña Ramírez[15], David Principe[16], Matthias R. Schreiber[11,12], Gerrit van der Plas[17]

[1] Facultad de Ingeniería y Ciencias, Núcleo de Astronomía, Universidad Diego Portales, Av. Ejercito 441. Santiago, Chile; [2] Millennium Nucleus “Protoplanetary Discs in ALMA Early Science”, Av. Ejercito 441. Santiago, Chile; [3] Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology, Rochester, NY 14623-5603, USA; [4] Joint ALMA Observatory, Alonso de Cordova 3107, Vitacura 763-0355, Santiago, Chile; [5] National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, Virginia, 22903-2475, USA; [6] Departamento de Astronomía, Universidad de Chile, Casilla 36-D Santiago, Chile; [7] European Space Astronomy Centre (ESA), Camino Bajo del Castillo s/n, 28692, Villanueva de la Cañada, Madrid, Spain; [8] Institute for Astronomy, University of Hawaii at Manoa, Honolulu, HI 96822, USA; [9] Department of Astronomy, University of California at Berkeley, Berkeley, CA 94720-3411; [10] ETH Zurich, Institute for Particle Physics and Astrophysics, Wolfgang-Pauli-Strasse 27, CH-8093, Zurich, Switzerland; [11] Facultad de Ciencias, Instituto de Física y Astronomía, Universidad de Valparaíso, Av. Gran Bretaa 1111, 5030 Casilla, Valparaśo, Chile; [12] Millennium Nucleus for Planet Formation, Universidad de Valparaíso, Av. Gran Bretaña 1111, Valparaíso, Chile; [13] Max Planck Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany; [14] Instituto de Astrofísica de La Plata y Facultad de Ciencias Astronómicas y Geofísicas, UNLAP, Paseo del Bosque s/n, La Plata, Argentina; [15] Centro de Astronomía (CITEVA), Universidad de Antofagasta, Av. Angamos 601, Antofagasta, Chile; [16] Massachusetts Institute of Technology, Kavli Institute for Astrophysics, Cambridge, MA, USA; [17] Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France

E-mail contact: lucas.cieza *at* mail.udp.cl

We introduce the Ophiuchus DIsc Survey Employing ALMA (ODISEA), a project aiming to study the entire population of Spitzer-selected protoplanetary discs in the Ophiuchus Molecular Cloud (∼300 objects) from both millimeter continuum and CO isotopologues data. Here we present 1.3 mm/230 GHz continuum images of 147 targets at 0.″2 (28 au) resolution and a typical rms of 0.15 mJy. We detect a total of 133 discs, including the individual components of 11 binary systems and 1 triple system. Fifty-three of these discs are spatially resolved. We find clear substructures (inner cavities, rings, gaps, and/or spiral arms) in 8 of the sources and hints of such structures in another 4 discs. We construct the disc luminosity function for our targets and perform comparisons to other regions. A simple conversion between flux and dust mass (adopting standard assumptions) indicates that all discs detected at 1.3 mm are massive enough to form one or more rocky planets. In contrast, only ∼50 discs (∼1/3 of the sample) have enough mass in the form of dust to form the canonical 10 $M_\oplus$ core needed to trigger runaway gas accretion and the formation of gas giant planets, although the total mass of solids already incorporated into bodies larger than cm scales is mostly unconstrained. The distribution in continuum disc sizes in our sample is heavily weighted towards compact discs: most detected discs have radii < 15 au, while only 23 discs (∼15% of the targets) have radii > 30 au.

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High resolution millimetre imaging of the CI Tau protoplanetary disc — a massive ensemble of protoplanets from 0.1–100 au

C.J. Clarke[1], M. Tazzari[1], A. Juhasz[1], G. Rosotti[1], R. Booth[1], S. Facchini[2], J.D. Ilee[1], C.M. Johns-Krull[3], M. Kama[1], F. Meru[1,4,5] and L. Prato[6]

[1] Institute of Astronomy, Madingley Road, Cambridge, CB3 OHA, UK; [2] Max-Planck-Institut für Extraterristische Physik, Giessenbachstrasse 1, 85748 Garching, DE; [3] Physics & Astronomy Dept., Rice University, 6100 Main St., Houston, TX 77005, USA; [4] Department of Physics, University of Warwick, Gibbet Hill Road, Coventry,CV4 7AL, UK; [5] Centre for Exoplanets and Habitability, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL, UK; [6] Lowell Observatory, 1400 West Mars Hill Road, Flagstaff, AZ 86001 USA

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

We present high resolution millimeter continuum imaging of the disc surrounding the young star CI Tau, a system hosting the first hot Jupiter candidate in a protoplanetary disc system. The system has extended mm emission on which are superposed three prominent annular gaps at radii ∼13, 39 and 100 au. We argue that these gaps are most likely to be generated by massive planets so that, including the hot Jupiter, the system contains four gas giant planets at an age of only 2 Myr. Two of the new planets are similarly located to those inferred in the famous HL Tau protoplanetary disc; in CI Tau, additional observational data enables a more complete analysis of the system properties than was possible for HL Tau. Our dust and gas dynamical modeling satisfies every available observational constraint and points to the most massive ensemble of exo-planets ever detected at this age, with its four planets spanning a factor 1000 in orbital radius.Our results show that the association between hot Jupiters and gas giants on wider orbits, observed in older stars, is apparently in place at an early evolutionary stage.

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Magnetically induced termination of giant planet formation

A.J. Cridland[1]

[1] Leiden Observatory, Leiden University, 2300 RA Leiden, the Netherlands

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

Here a physical model for terminating giant planet formation is outlined and compared to other methods of late-stage giant planet formation. As has been pointed out before, gas accreting into a gap and onto the planet will encounter the planetary dynamo-generated magnetic field. The planetary magnetic field produces an effective cross section through which gas is accreted. Gas outside this cross section is recycled into the protoplanetary disk, hence only a

fraction of mass that is accreted into the gap remains bound to the planet. This cross section inversely scales with the planetary mass, which naturally leads to stalled planetary growth late in the formation process. We show that this method naturally leads to Jupiter-mass planets and does not invoke any artificial truncation of gas accretion, as has been done in some previous population synthesis models. The mass accretion rate depends on the radius of the growing planet after the gap has opened, and we show that so-called hot-start planets tend to become more massive than cold-start planets. When this result is combined with population synthesis models, it might show observable signatures of cold-start versus hot-start planets in the exoplanet population.

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Simultaneous spectral energy distribution and near-infrared interferometry modeling of HD 142666

Claire L Davies[1], Stefan Kraus[1], Tim J Harries[1], Alexander Kreplin[1], John D Monnier[2], Aaron Labdon[1], Brian Kloppenborg[3], David M Acreman[1], Fabien Baron[3], Rafael Millan-Gabet[4], Judit Sturmann[5], Laszlo Sturmann[5] and Theo A ten Brummelaar[5]

[1] Astrophysics Group, School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK; [2] Department of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA; [3] Department of Physics and Astronomy, Georgia State University, Atlanta, GA, USA; [4] Infrared Processing and Analysis Center, California Institute of Technology, Pasadena, CA, 91125, USA; [5] The CHARA Array of Georgia State University, Mount Wilson Observatory, Mount Wilson, CA 91203, USA

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

We present comprehensive models of Herbig Ae star, HD 142666, which aim to simultaneously explain its spectral energy distribution (SED) and near-infrared (NIR) interferometry. Our new submilliarcsecond resolution CHARA (CLASSIC and CLIMB) interferometric observations, supplemented with archival shorter baseline data from VLTI/PIONIER and the Keck Interferometer, are modeled using centro-symmetric geometric models and an axisymmetric radiative transfer code. CHARAs 330 m baselines enable us to place strong constraints on the viewing geometry, revealing a disk inclined at 58° from face-on with a 160° major axis position angle. Disk models imposing vertical hydrostatic equilibrium provide poor fits to the SED. Models accounting for disk scale height inflation, possibly induced by turbulence associated with magneto-rotational instabilities, and invoking grain growth to $\gtrsim 1\,\mu$m size in the disk rim are required to simultaneously reproduce the SED and measured visibility profile. However, visibility residuals for our best model fits to the SED indicate the presence of unexplained NIR emission, particularly along the apparent disk minor axis, while closure phase residuals indicate a more centro-symmetric emitting region. In addition, our inferred 58° disk inclination is inconsistent with a disk-based origin for the UX Ori-type variability exhibited by HD 142666. Additional complexity, unaccounted for in our models, is clearly present in the NIR-emitting region. We propose the disk is likely inclined toward a more edge-on orientation and/or an optically thick outflow component also contributes to the NIR circumstellar flux.

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The study of a system of H II regions toward l = 24.8 deg, b = 0.1 deg at the Galactic bar - Norma arm interface

L. K. Dewangan[1], J. S. Dhanya[2], D. K. Ojha[3] and I. Zinchenko[4]

[1] Physical Research Laboratory, Navrangpura, Ahmedabad - 380 009, India; [2] Malaviya National Institute of Technology (MNIT), Jaipur 302 017, India; [3] Department of Astronomy and Astrophysics, Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India; [4] Institute of Applied Physics of the Russian Academy of Sciences, 46 Ulyanov st., Nizhny Novgorod 603950, Russia

E-mail contact: lokeshd *at* prl.res.in

To probe the star formation (SF) process, we present a thorough multi-wavelength investigation of several H II regions located toward l = 24.8 deg, b = 0.1 deg. A system of at least five H II regions including the mid-infrared bubble N36 (hereafter "system N36"; extension ∼35 pc) is observationally investigated, and is located at a distance of 6.0 kpc. With this distance, the system N36 is found to be situated at the interface of the Galactic bar and the Norma Galactic arm in our Galaxy, where one may expect the collisions of molecular clouds due to the bar potential. Each H II region (dynamical age ∼0.4–1.3 Myr) in the system is powered by an O-type star. The system contains 27 ATLASGAL dust clumps at 870 μm. Several clumps are massive ($> 10^3$ $M_\odot$), and have high bolometric luminosity ($> 10^3$ $L_\odot$). Using the GRS ^{13}CO line data, in the direction of the system N36, two velocity components are found around 109 and 113 km s^{-1}, and are linked in the velocity space. The morphological analysis of ^{13}CO favours the presence of interacting molecular clouds in the system. Four H II regions and two 6.7 GHz masers are spatially observed at the common areas of the two clouds. The analysis of the *Spitzer* photometric data also traces the noticeable SF activity in the system. Considering the observational outcomes, the formation of O-type stars (including ongoing SF) in the system appears to be triggered by the collisions of molecular clouds at the bar-arm interface.

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Multiple Disk Gaps and Rings Generated by a Single Super-Earth: II. Spacings, Depths, and Number of Gaps, with Application to Real Systems

Ruobing Dong[1,2], Shengtai Li[3], Eugene Chiang[4] and Hui Li[3]

[1] Department of Physics & Astronomy, University of Victoria, Victoria, BC, V8P 1A1, Canada; [2] Steward Observatory, University of Arizona, Tucson, AZ, 85719, USA; [3] Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA; [4] Department of Astronomy, University of California at Berke- ley, Berkeley, CA 94720, USA

E-mail contact: rbdong *at* gmail.com

ALMA has found multiple dust gaps and rings in a number of protoplanetary disks, including HL Tau and TW Hya, in continuum emission at millimeter wavelengths. The origin of such structures is in debate. Recently, we documented how one super-Earth planet can open multiple (up to five) dust gaps in a disk with low viscosity ($\alpha \lesssim 10^{-4}$). In this paper, we examine how the positions, depths, and total number of gaps opened by one planet depend on input parameters, and apply our results to real systems. Gap locations (equivalently, spacings) are the easiest metric to use when making comparisons between theory and observations, as positions can be robustly measured. We fit the locations of gaps empirically as functions of planet mass and disk aspect ratio. We find that the locations of the double gaps in HL Tau and TW Hya, and of all three gaps in HD 163296, are consistent with being opened by a sub-Saturn mass planet. This scenario predicts the locations of other gaps in HL Tau and TW Hya, only some of which appear consistent with current observations. We also show how the Rossby wave instability may develop at the edges of several gaps and result in multiple dusty vortices, all caused by one planet. A planet as low in mass as Mars may produce multiple dust gaps in the terrestrial planet forming region.

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Clumpy shocks as the driver of velocity dispersion in molecular clouds: the effects of self-gravity and magnetic fields

D.H. Forgan[1] and I.A. Bonnell[1]

[1] SUPA, School of Physics & Astronomy, University of St Andrews, North Haugh, St Andrews, Scotland, KY16 9SS, UK

E-mail contact: dhf3 *at* st-andrews.ac.uk

We revisit an alternate explanation for the turbulent nature of molecular clouds - namely, that velocity dispersions matching classical predictions of driven turbulence can be generated by the passage of clumpy material through a shock. While previous work suggested this mechanism can reproduce the observed Larson relation between velocity dispersion and size scale ($\sigma \propto L^\Gamma$ with $\Gamma \approx 0.5$), the effects of self-gravity and magnetic fields were not considered. We run a series of smoothed particle magnetohydrodynamics experiments, passing clumpy gas through a shock in the presence of a combination of self-gravity and magnetic fields. We find powerlaw relations between σ and L throughout, with indices ranging from $\Gamma = 0.3 - 1.2$. These results are relatively insensitive to the strength and geometry of magnetic

fields, provided that the shock is relatively strong. Γ is strongly sensitive to the angle between the gas' bulk velocity and the shock front, and the shock strength (compared to the gravitational boundness of the pre-shock gas). If the origin of the $\sigma - L$ relation is in clumpy shocks, deviations from the standard Larson relation constrain the strength and behaviour of shocks in spiral galaxies.

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The *Gaia* DR2 view of the Gamma Velorum cluster: resolving the 6D structure

E. Franciosini[1], G. G. Sacco[1], R. D. Jeffries[2], F. Damiani[3], V. Roccatagliata[1], D. Fedele[1] and S. Randich[1]

[1] INAF - Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125, Florence, Italy; [2] Astrophysics Group, Keele University, Keele, Staffordshire ST5 5BG, United Kingdom; [3] INAF - Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134, Palermo, Italy

E-mail contact: francio *at* arcetri.inaf.it

Gaia-ESO Survey observations of the young Gamma Velorum cluster led to the discovery of two kinematically distinct populations, Gamma Vel A and B, respectively, with population B extended over several square degrees in the Vela OB2 association. Using the *Gaia* DR2 data for a sample of high-probability cluster members, we find that the two populations differ not only kinematically, but are also located at different distances along the line of sight, with the main cluster Gamma Vel A being closer. A combined fit of the two populations yields $\varpi_A = 2.895 \pm 0.008$ mas and $\varpi_B = 2.608 \pm 0.017$ mas, with intrinsic dispersions of 0.038 ± 0.011 mas and 0.091 ± 0.016 mas, respectively. This translates into distances of $345.4^{+1.0+12.4}_{-1.0-11.5}$ pc and $383.4^{+2.5+15.3}_{-2.5-14.2}$ pc, respectively, showing that Gamma Vel A is closer than Gamma Vel B by ~ 38 pc. We find that the two clusters are nearly coeval, and that Gamma Vel B is expanding. We suggest that Gamma Vel A and B are two independent clusters located along the same line of sight.

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Synthetic [CII] emission maps of a simulated molecular cloud in formation

A. Franeck[1], S. Walch[1], D. Seifried[1], S.D. Clarke[1], V. Ossenkopf-Okada[1], S.C.O. Glover[2], R.S. Klessen[2,3], P. Girichidis[4], T. Naab[5], R. Wünsch[6], P.C. Clark[7], E. Pellegrini[2], T. Peters[5]

[1] I. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Germany; [2] Universität Heidelberg, Zentrum für Astronomie, Institut für Theoretische Astrophysik, Albert-Ueberle-Straße 2, D-69120 Heidelberg, Germany; [3] Universität Heidelberg, Institut für wissenschaftliches Rechnen (IWR), Im Neuenheimer Feld 205, 69120 Heidelberg; [4] Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, D-14482 Potsdam, Germany; [5] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Straße 1, D-85748 Garching, Germany; [6] Astronomical Institute, Czech Academy of Sciences, Bocni II 1401, CZ-141 00 Prague, Czech Republic; [7] School of Physics & Astronomy, Cardiff University, 5 The Parade, Cardiff CF24 3AA, Wales, UK

E-mail contact: franeck *at* ph1.uni-koeln.de

The C^+ ion is an important coolant of interstellar gas, and so the [CII] fine structure line is frequently observed in the interstellar medium. However, the physical and chemical properties of the [CII]-emitting gas are still unclear. We carry out non-LTE radiative transfer simulations with RADMC-3D to study the [CII] line emission from a young, turbulent molecular cloud before the onset of star formation, using data from the SILCC-Zoom project. The [CII] emission is optically thick over 40% of the observable area with $I_{[CII]} > 0.5$ K km s^{-1}. To determine the physical properties of the [CII] emitting gas, we treat the [CII] emission as optically thin. We find that the [CII] emission originates primarily from cold, moderate density gas ($40 \lesssim T \lesssim 65$ K and $50 \lesssim n \lesssim 440$ cm^{-3}), composed mainly of atomic hydrogen and with an effective visual extinction between ∼0.50 and ∼0.91. Gas dominated by molecular hydrogen contributes only $\lesssim$20% of the total [CII] line emission. Thus, [CII] is not a good tracer for CO-dark H_2 at this early phase in the cloud's lifetime. We also find that the total gas, H and C^+ column densities are all correlated with the integrated [CII] line emission, with power law slopes ranging from 0.5 to 0.7. Further, the median ratio between the total column density

and the [CII] line emission is $Y_{\rm CII} \approx 1.1 \times 10^{21}$ cm^{-2} (K km s^{-1})$^{-1}$, and $Y_{\rm CII}$ scales with $I_{\rm [CII]}{}^{-0.3}$. We expect $Y_{\rm CII}$ to change in environments with a lower or higher radiation field than simulated here.

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On the indeterministic nature of star formation on the cloud scale

Sam Geen[1], Stuart K Watson[2], Joakim Rosdahl[3], Rebekka Bieri[4], Ralf S Klessen[1,5] and Patrick Hennebelle[6]

[1] Universität Heidelberg, Zentrum für Astronomie, Institut für Theoretische Astrophysik, Albert-Ueberle-Str. 2, 69120 Heidelberg, Germany; [2] Department of Comparative Linguistics, University of Zürich, Plattenstrasse 54, CH-8032 Zürich, Switzerland; [3] Univ Lyon, Univ Lyon1, ENS de Lyon, CNRS, Centre de Recherche Astrophysique de Lyon UMR5574, F-69230, Saint-Genis-Laval, France; [4] Max-Planck-Institute for Astrophysics, Karl-Schwartzschild-Strasse 1, Garching, Germany; [5] Universität Heidelberg, Interdisziplinäres Zentrum für Wissenschaftliches Rechnen, INF 205, 69120, Heidelberg, Germany; [6] Laboratoire AIM, Paris-Saclay, CEA/IRFU/SAp - CNRS - Université Paris Diderot, 91191, Gif-sur-Yvette Cedex, France

E-mail contact: sam.geen *at* uni-heidelberg.de

Molecular clouds are turbulent structures whose star formation efficiency (SFE) is strongly affected by internal stellar feedback processes. In this paper, we determine how sensitive the SFE of molecular clouds is to randomized inputs in the star formation feedback loop, and to what extent relationships between emergent cloud properties and the SFE can be recovered. We introduce the YULE suite of 26 radiative magnetohydrodynamic simulations of a 10 000 solar mass cloud similar to those in the solar neighbourhood. We use the same initial global properties in every simulation but vary the initial mass function sampling and initial cloud velocity structure. The final SFE lies between 6 and 23 per cent when either of these parameters are changed. We use Bayesian mixed-effects models to uncover trends in the SFE. The number of photons emitted early in the cluster's life and the length of the cloud provide the strongest predictors of the SFE. The H II regions evolve following an analytic model of expansion into a roughly isothermal density field. The more efficient feedback is at evaporating the cloud, the less the star cluster is dispersed. We argue that this is because if the gas is evaporated slowly, the stars are dragged outwards towards surviving gas clumps due to the gravitational attraction between the stars and gas. While star formation and feedback efficiencies are dependent on non-linear processes, statistical models describing cloud-scale processes can be constructed.

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The Serpens filament: at the onset of slightly supercritical collapse

Y. Gong[1,2], G. X. Li[3,4], R. Q. Mao[2], C. Henkel[1,5,6], K. M. Menten[1], M. Fang[7], M. Wang[2] and J. X. Sun[2]

[1] Max-Planck Institute für Radioastronomy, Auf dem Hügel 69, 53121 Bonn, Germany; [2] Purple Mountain Observatory & Key Laboratory for Radio Astronomy, Chinese Academy of Sciences, 2 West Beijing Road, 210008 Nanjing, P.R. China; [3] University Observatory Munich, Scheinerstrasse 1, D-81679 München, Germany; [4] South-Western Institute for Astronomy Research, Yunnan University, Kunming, Yunnan 650500, P.R. China; [5] Astronomy Department, Faculty of Science, King Abdulaziz University, P.O. Box 80203, Jeddah 21589, Saudi Arabia; [6] Xinjiang Astronomical Observatory, Chinese Academy of Sciences, 830011 Urumqi, China; [7] Department of Astronomy, University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721, USA

E-mail contact: ygong *at* mpifr-bonn.mpg.de

The Serpens filament, as one of the nearest infrared dark clouds, is regarded as a pristine filament at a very early evolutionary stage of star formation. In order to study its molecular content and dynamical state, we mapped this filament in seven species including $C^{18}O$, HCO^+, HNC, HCN, N_2H^+, CS, and CH_3OH. Among them, HCO^+, HNC, HCN, and CS show self-absorption, while $C^{18}O$ is most sensitive to the filamentary structure. A kinematic analysis demonstrates that this filament forms a velocity-coherent (trans-)sonic structure, a large part of which is one of the most quiescent regions in the Serpens cloud. Widespread $C^{18}O$ depletion is found throughout the Serpens filament. Based on the Herschel dust-derived H_2 column density map, the line mass of the filament is 36–41 $M_\odot$ pc^{-1}, and its full width at half maximum width is 0.17±0.01 pc, while its length is ≈ 1.6 pc. The inner radial column density profile of this filament can be well fitted with a Plummer profile with an exponent of 2.2±0.1, a scale radius of 0.018 ± 0.003 pc, and a central density of $(4.0 \pm 0.8) \times 10^4$ cm^{-3}. The Serpens filament appears to be slightly supercritical. The widespread blue-skewed HNC and CS line profiles and HCN hyperfine line anomalies across this filament indicate radial infall in parts of the Serpens filament. $C^{18}O$ velocity gradients also indicate accretion flows along the filament. The velocity and density structures suggest that such accretion flows are likely due to a longitudinal collapse parallel to the filament's long axis. Both the radial infall rate (∼72 $M_\odot$ Myr^{-1}, inferred from HNC and CS blue-skewed profiles) and the longitudinal accretion rate (∼10 $M_\odot$ Myr^{-1}, inferred from $C^{18}O$ velocity gradients) along the Serpens filament are lower than all previously reported values in other filaments. This indicates that the Serpens filament lies at an early evolutionary stage when collapse has just begun, or that thermal and non-thermal support are effective in providing support against gravity.

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Multiple star systems in the Orion nebula

GRAVITY collaboration: Martina Karl[1], Oliver Pfuhl[1], Frank Eisenhauer[1], Reinhard Genzel[1,2], Rebekka Grellmann[3], Maryam Habibi[1], Roberto Abuter[4], Matteo Accardo[4], António Amorim[5], Narsireddy Anugu[6], Gerardo Ávila[4], Myriam Benisty[7], Jean-Philippe Berger[7], Nicolas Blind[8], Henri Bonnet[4], Pierre Bourget[9], Wolfgang Brandner[10], Roland Brast[4], Alexander Buron[1], Alessio Caratti o Garatti[10,15], Frédéric Chapron[11], Yann Clénet[11], Claude Collin[11], Vincent Coudé du Foresto[11], Willem-Jan de Wit[9], Tim de Zeeuw[1,12], Casey Deen[1], Franoise Delplancke-Ströbele[4], Roderick Dembet[4], Frédéric Derie[4], Jason Dexter[1], Gilles Duvert[7], Monica Ebert[10], Andreas Eckart[3,13], Michael Esselborn[4], Pierre Fédou[11], Gert Finger[4], Paulo Garcia[6,9], Cesar Enrique Garcia Dabo[4], Rebeca Garcia Lopez[10,15], Feng Gao[1], Éric Gendron[11], Stefan Gillessen[1], Frédéric Gonté[4], Paulo Gordo[5], Ulrich Grözinger[10], Patricia Guajardo[9], Sylvain Guieu[7], Pierre Haguenauer[4], Oliver Hans[1], Xavier Haubois[9], Marcus Haug[1,4], Frank Haumann[1], Thomas Henning[10], Stefan Hippler[10], Matthew Horrobin[3], Armin Huber[10], Zoltan Hubert[11], Norbert Hubin[4], Christian A. Hummel[4], Gerd Jakob[4], Lieselotte Jochum[4], Laurent Jocou[7], Andreas Kaufer[9], Stefan Kellner[1,13], Sarah Kendrew[10,14], Lothar Kern[4], Pierre Kervella[11], Mario Kiekebusch[4], Ralf Klein[10], Rainer Köhler[10,16], Johan Kolb[9], Martin Kulas[10], Sylvestre Lacour[11], Vincent Lapeyrère[11], Bernard Lazareff[7], Jean-Baptiste Le Bouquin[7], Pierre Léna[11], Rainer Lenzen[10], Samuel Lévêque[4], Chien-Cheng Lin[10], Magdalena Lippa[1], Yves Magnard[7], Leander Mehrgan[4], Antoine Mérand[4], Thibaut Moulin[7], Eric Müller[4], Friedrich Müller[10], Udo Neumann[10], Sylvain Oberti[4], Thomas Ott[1], Laurent Pallanca[9], Johana Panduro[10], Luca Pasquini[4], Thibaut Paumard[11], Isabelle Percheron[4], Karine Perraut[7], Guy Perrin[11], Andreas Pflüger[1], Thanh Phan Duc[4], Philipp M. Plewa[1], Dan Popovic[4], Sebastian Rabien[1], Andrés Ramírez[9], Jose Ramos[10], Christian Rau[1], Miguel Riquelme[9], Gustavo Rodríguez-Coira[11], Ralf-Rainer Rohloff[10], Alejandra Rosales[1], Gérard Rousset[11], Joel Sanchez Bermudez[9,10], Silvia Scheithauer[10], Markus Schöller[4], Nicolas Schuhler[9], Jason Spyromilio[4], Odele Straub[11], Christian Straubmeier[3], Eckhard Sturm[1], Marcos Suarez[4], Konrad R.W. Tristram[9], Noel Ventura[7], Frédéric Vincent[11], Idel Waisberg[1], Imke Wank[3], Felix Widmann[1], Ekkehard Wieprecht[1], Michael Wiest[3], Erich Wiezorrek[1], Markus Wittkowski[4], Julien Woillez[4], Burkhard Wolff[4], Senol Yazici[1,3], Denis Ziegler[11], Gérard Zins[9]

[1] MPE - Max Planck Institute for extraterrestrial Physics, Giessenbachstr., 85741 Garching, Germany; [2] Department of Physics, Le Conte Hall, University of California, Berkeley, CA 94720, USA; [3] 1. Physikalisches Institut, Universität zu Köln, Zlpicher Str. 77, 50937 Köln, Germany; [4] European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching, Germany; [5] CENTRA – Centro de Astrofísica e Gravitação, IST, Universidade de Lisboa, P-1049-001 Lisboa, Portugal; Universidade de Lisboa - Faculdade de Ciências, Campo Grande, 1749-016 Lisboa, Portugal; [6] CENTRA – Centro de Astrofísica e Gravitação, IST, Universidade de Lisboa, P-1049-001 Lisboa, Portugal; Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal; [7] Univ. Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France; [8] Observatoire de Genève, Université de Genève, 51 Ch. des Maillettes, 1290 Versoix, Switzerland; [9] European Southern Observatory, Casilla 19001, Santiago 19, Chile; [10] MPIA - Max-Planck-

Institut fr Astronomie, Königstuhl 17, 69117, Heidelberg, Germany; [11] LESIA - Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Univ. Paris Diderot, Sorbonne Paris Cité, 5 place Jules Janssen, 92195 Meudon, France; [12] Sterrewacht Leiden, Leiden University, Postbus 513, 2300 RA Leiden, The Netherlands; [13] Max-Planck-Institute for Radio Astronomy, Auf dem Hgel 69, 53121 Bonn, Germany; [14] ESA - European Space Agency, Space Telescope Science Institute, 3700 San Martin Drive, Baltimore MD 21218, USA; [15] Dublin Institute for Advanced Studies, Astronomy & Astrophysics Section, 31 Fitzwilliam Place, D02 XF86, Dublin, Ireland; [16] University of Vienna, Universitätsring 1, 1010 Wien, Austria

E-mail contact: martina.karl@tum.de

This work presents an interferometric study of the massive-binary fraction in the Orion Trapezium Cluster with the recently comissioned GRAVITY instrument. We observe a total of 16 stars of mainly OB spectral type. We find three previously unknown companions for θ^1 Ori B, θ^2 Ori B, and θ^2 Ori C. We determine a separation for the previously suspected companion of NU Ori. We confirm four companions for θ^1 Ori A, θ^1 Ori C, θ^1 Ori D, and θ^2 Ori A, all with substantially improved astrometry and photometric mass estimates. We refine the orbit of the eccentric high-mass binary θ^1 Ori C and we are able to derive a new orbit for θ^1 Ori D. We find a system mass of 21.7 $M_\odot$ and a period of 53 days. Together with other previously detected companions seen in spectroscopy or direct imaging, eleven of the 16 high-mass stars are multiple systems. We obtain a total number of 22 companions with separations up to 600 AU. The companion fraction of the early B and O stars in our sample is about 2, significantly higher than in earlier studies of mostly OB associations. The separation distribution hints towards a bimodality. Such a bimodality has been previously found in A stars, but rarely in OB binaries, which up to this point have been assumed to be mostly compact with a tail of wider companions. We also do not find a substantial population of equal-mass binaries. The observed distribution of mass ratios declines steeply with mass, and like the direct star counts, indicates that our companions follow a standard power law initial mass function. Again, this is in contrast to earlier findings of flat mass ratio distributions in OB associations. We exclude collision as a dominant formation mechanism but find no clear preference for core accretion or competitive accretion.

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VISION - Vienna survey in Orion. III. Young stellar objects in Orion A

Josefa E. Großschedl[1], João Alves[1], Paula S. Teixeira[1,2,3], Hervé Bouy[4], Jan Forbrich[1,5,6], Charles J. Lada[6], Stefan Meingast[1], Álvaro Hacar[1,7], Joana Ascenso[8], Christine Ackerl[1], Birgit Hasenberger[1], Rainer Köhler[1], Karolina Kubiak[1], Irati Larreina[1], Lorenz Linhardt[9], Marco Lombardi[10], Torsten Möller[9]

[1]Universität Wien, Institut für Astrophysik, Türkenschanzstrasse 17, 1180 Wien, Austria; [2]ICCUB, Univ. de Barcelona (IEEC-UB), Martí Franquès 1, E-08028 Barcelona; [3]SUPA, School of Physics and Astronomy, Univ. of St. Andrews, North Haugh, Fife KY16 9SS, UK; [4]Laboratoire d'Astrophysique de Bordeaux, Univ. de Bordeaux, Allée Geoffroy Saint-Hilaire, CS 50023, 33615 PESSAC CEDEX, F; [5]Centre for Astrophysics Research, School of Physics, Astronomy and Mathematics, Univ. of Hertfordshire, College Lane, Hatfield AL10 9AB, UK; [6]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA; [7]Leiden Observatory, Niels Bohrweg 2, 2333 CA Leiden, NL; [8]Univ. do Porto, Dept. de Engenharia Física da Faculdade de Engenharia, Rua Dr. Roberto Frias, P-4200-465, Porto; [9]Univ. Wien, Fakultät für Informatik, Währinger Straße 29/S6, A-1090 Wien; [10]Univ. of Milan, Dept. of Physics, via Celoria 16, I-20133 Milan;

E-mail contact: josefa.elisabeth.grossschedl *at* univie.ac.at

We extend and refine the existing young stellar object (YSO) catalogs for the Orion A molecular cloud, the closest massive star-forming region to Earth. This updated catalog is driven by the large spatial coverage (18.3 deg^2, $\sim$950 pc^2), seeing limited resolution ($\sim$0.7″), and sensitivity ($K_s < 19$ mag) of the ESO-VISTA near-infrared survey of the Orion A cloud (VISION). Combined with archival mid- to far-infrared data, the VISTA data allow for a refined and more robust source selection. We estimate that among previously known protostars and pre-main-sequence stars with disks, source contamination levels (false positives) are at least $\sim$7% and $\sim$2.5% respectively, mostly due to background galaxies and nebulosities. We identify 274 new YSO candidates using VISTA/*Spitzer* based selections within previously analyzed regions, and VISTA/*WISE* based selections to add sources in the surroundings, beyond previously analyzed regions. The *WISE* selection method recovers about 59% of the known YSOs in Orion A's low-mass star-forming part L1641, which shows what can be achieved by the all-sky *WISE* survey in combination with deep near-infrared data in regions

without the influence of massive stars. The new catalog contains 2978 YSOs, which were classified based on the de-reddened mid-infrared spectral index into 188 protostars, 184 flat-spectrum sources, and 2606 pre-main-sequence stars with circumstellar disks. We find a statistically significant difference in the spatial distribution of the three evolutionary classes with respect to regions of high dust column-density, confirming that flat-spectrum sources are at a younger evolutionary phase compared to Class IIs, and are not a sub-sample seen at particular viewing angles.

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H_2CO ortho-to-para ratio in the protoplanetary disk HD 163296

V.V. Guzmán[1], K.I. Öberg[2], J. Carpenter[1], R. Le Gal[2], C. Qi[2], and J. Pagues[2]

[1] Joint ALMA Observatory (JAO), Alonso de Córdova 3107 Vitacura, Santiago de Chile, Chile; [2] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: viviana.guzman *at* alma.cl

Ortho-to-para (o/p) ratios of species like water, ammonia and formaldehyde (H_2CO) are believed to encode information about the formation history of the molecule. Measurements of o/p ratios in protoplanetary disks could thus be used to constrain their physical and chemical histories. We present the first measurement of the H_2CO o/p ratio in a protoplanetary disk, using three ortho and two para lines observed with the Sub-millimeter Array (SMA) combined with one highly resolved measurement of a single H_2CO line with ALMA toward the disk around Herbig Ae star HD 163296. We find a disk-averaged H_2CO o/p ratio of 1.8–2.8 (depending on the assumed disk structure), corresponding to a spin temperature of 11–22 K. We also derive a rotational temperature of 24 K from the flux ratio of the three ortho lines. The observed spatial distribution, as seen by ALMA, as well as the rotational temperature and the o/p ratio, at the large scales the SMA is most sensitive to, are consistent with a low-temperature formation pathway, most likely grain surface chemistry, of H_2CO in this disk.

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High spectral resolution observations toward Orion BN at 6 μm: no evidence for hot water.

Nick Indriolo[1], Jonathan C. Tan[2,3], A. C. A. Boogert[4], C. N. DeWitt[5], E. J. Montiel[6], D. A. Neufeld[7] and M. J. Richter[6]

[1] Space Telescope Science Institute, Baltimore, MD 21218, USA; [2] Department of Space, Earth & Environment, Chalmers University of Technology, SE-412 93 Gothenburg, Sweden; [3] Department of Astronomy, University of Virginia, Charlottesville, VA, 22904, USA; [4] Institute for Astronomy, University of Hawaii at Manoa, Honolulu, HI, 96822, USA; [5] USRA, SOFIA, NASA Ames Research Center MS 232-11, Moffett Field, CA 94035, USA; [6] Department of Physics, University of California Davis, Davis, CA, 95616, USA; [7] Department of Physics & Astronomy, Johns Hopkins University, Baltimore, MD 21218, USA

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

The Becklin–Neugebauer (BN) object in Orion has a large proper motion and radial velocity with respect to the gas and other stars in the region where it is presumed to have formed. Multiple dynamical interaction scenarios have been proposed to explain this motion. In one case BN is thought to have interacted with stars in the Trapezium cluster, while in another it is thought to have interacted with source I while deeply embedded in molecular gas. If there is dense gas that has been retained in close proximity to BN, it may be evidence that the latter scenario is favored. We observed BN at high spectral resolution in three windows near 6 μm using the Echelon-Cross-Echelle Spectrograph on board the Stratospheric Observatory for Infrared Astronomy targeting the ν_2 vibrational band of H_2O. Absorption from only three transitions of H_2O is detected, and through kinematic analysis is associated with cool, dense foreground gas, not BN itself. We find no evidence for H_2O absorption or emission at the systemic velocity of BN.

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Capture and Escape: The Dependence of Radiation Forces on Clumping in Dusty Envelopes

Peter H. Jumper[1] **and Christopher D. Matzner**[1]

[1] Department of Astronomy and Astrophysics, University of Toronto, 50 St. George Street, Toronto, Ontario, M5S 3H4, Canada

E-mail contact: jumper *at* astro.utoronto.ca

Dust barriers effectively capture the photon momentum of a central light source, but low-density channels, along with re-emission at longer wavelengths, enhance its escape. We use Monte Carlo simulations to study the effects of inhomogeneity on radiation forces imparted to a dust envelope around a central star. We survey the strength and scale of an inhomogeneous perturbation field, as well as the optical depth of its spherical reference state. We run at moderate numerical resolution, relying on our previous resolution study for calibration of the associated error. We find that inhomogeneities matter most when their scale exceeds the characteristic mean free path. As expected, they tend to reduce the net radiation force and extend its range; however, there is significant variance among realizations. Within our models, force integrals correlate with the emergent spectral energy distribution, given a specified set of dust properties. A critical issue is the choice of integral measures of the radiation force: for strong deviations from spherical symmetry the relevant measures assess radial forces relative to the cloud centre of mass. Of these, we find the virial term due to radiation to be the least stochastic of several integral measures in the presence of inhomogeneities.

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CO observations toward the isolated mid-infrared bubble GAL 334.53+00.83 (S44): External triggering of O-star formation by a cloud-cloud collision

Mikito Kohno[1]**, Kengo Tachihara**[1]**, Shinji Fujita**[1]**, Yusuke Hattori**[1]**, Kazufumi Torii**[2]**, Atsushi Nishimura**[1]**, Misaki Hanaoka**[1]**, Satoshi Yoshiike**[1]**, Rei Enokiya**[1]**, Keisuke Hasegawa**[1]**, Akio Ohama**[1]**, Hidetoshi Sano**[1,3]**, Hiroaki Yamamoto**[1] **and Yasuo Fukui**[1,3]

[1] Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8601, Japan; [2] Nobeyama Radio Observatory, National Astronomical Observatory of Japan (NAOJ), National Institutes of Natural Sciences (NINS), 462-2, Nobeyama, Minamimaki, Minamisaku, Nagano 384-1305, Japan; [3] Institute for Advanced Research, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan

E-mail contact: mikito *at* a.phys.nagoya-u.ac.jp

We have performed a multi-wavelength study of the mid-infrared bubble GAL 334.53+00.83 (S44) to investigate the origin of isolated high-mass star(s) and the star-formation process around the bubble formed by the HII region. In this paper, we report the results of new CO observations (^{12}CO, ^{13}CO J =1–0, and ^{12}CO J =3–2) toward the isolated bubble GAL 334.53+00.83 using the NANTEN2, Mopra, and ASTE radio telescopes. We found two velocity components in the direction of the bubble, at -84 km s^{-1} and -79 km s^{-1}. These two clouds are likely to be physically associated with the bubble, because of the enhanced ^{12}CO J =3–2/1–0 intensity ratio from a ring-like structure affected by ultraviolet radiation from embedded high-mass star(s) and from the morphological correspondence between the 8 μm emission and the CO distribution. Assuming a single object, we estimate the spectral type of the embedded star inside the bubble to be O8.5-9 from the radio-continuum free-free emission. We hypothesize that the two clouds collided with each other 3 Myr ago, triggering the formation of the isolated high-mass star in GAL 334.53+00.83, as also occurred with RCW 120 and RCW 79. We argue that this scenario can explain the origin of the isolated O-star inside the bubble.

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First hydrodynamics simulations of radiation forces and photoionization feedback in massive star formation

Rolf Kuiper[1] **and Takashi Hosokawa**[2]

[1] Institute of Astronomy and Astrophysics, University of Tübingen, Auf der Morgenstelle 10, 72076, Tübingen, Ger-

many; [2] Department of Physics, Kyoto University, Kyoto, 606-8502, Japan

E-mail contact: rolf.kuiper *at* uni-tuebingen.de

Aims: We present the first simulations of the formation and feedback of massive stars which account for radiation forces as well as photoionization feedback (along with protostellar outflows). In two different accretion scenarios modeled, we determine the relative strength of these feedback components and derive the size of the reservoir from which the forming stars gained their masses.
Method: We performed direct hydrodynamics simulations of the gravitational collapse of high-density mass reservoirs toward the formation of massive stars including self-gravity, stellar evolution, protostellar outflows, continuum radiation transport, photoionization, and the potential impact of ram pressure from large-scale gravitational infall. For direct comparison, we executed these simulations with and without the individual feedback components.
Results: Protostellar outflows alone limit the stellar mass growth only in an accretion scenario with a finite mass reservoir; when including accretion and ram pressure from large scales (> 0.1 pc), protostellar outflows do not limit stellar mass growth at all. Photoionization and HII regions dominate the feedback ladder only at later times, after the star has already contracted down to the zero-age main sequence, and only on large scales. Specifically, photoionization yields a broadening of the bipolar outflow cavities and a reduction of the gravitational infall momentum by about 50%, but does not limit the stellar mass accretion. On the other hand, we find radiation forces restrain the gravitational infall toward the circumstellar disk, impact the gravito-centrifugal equilibrium at the outer edge of the disk, and eventually shut down stellar accretion completely. The most massive star formed in the simulations accreted 95 $M_\odot$ before disk destruction; this mass was drawn-in from an accretion reservoir of ≈ 240 $M_\odot$ and ≈ 0.24 pc in radius.
Conclusion: In the regime of very massive stars, the final mass of these stars is controlled by their own radiation force feedback.

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High-resolution ALMA Study of the Proto-Brown-Dwarf Candidate L328-IRS

Chang Won Lee[1,2], Gwanjeong Kim[1,2,3], Philip C. Myers[4], Masao Saito[5], Shinyoung Kim[1,2], Woojin Kwon[1,2], A-Ran Lyo[1], Archana Soam[1], and Mi-Ryang Kim[1]

[1] Korea Astronomy & Space Science Institute, 776 Daedeokdae-ro, Yuseong-gu, Daejeon, Republic of Korea; [2] Korea University of Science & Technology, 217 Gajungro, Yuseong-gu, Daejeon, 305-333, Republic of Korea; [3] Nobeyama Radio Observatory, National Astronomical Observatory of Japan, National Institutes of Natural Sciences, Nobeyama, Minamimaki, Minamisaku, Nagano 384-1305, Japan; [4] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA; [5] National Astronomical Observatory of Japan, National Institutes of Natural Sciences, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan

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

This paper presents our observational attempts to precisely measure the central mass of a proto-brown dwarf candidate, L328-IRS, in order to investigate whether L328-IRS is in the substellar mass regime. Observations were made for the central region of L328-IRS with the dust continuum and CO isotopologue line emission at ALMA band 6, discovering the detailed outflow activities and a deconvolved disk structure of a size of $\sim$87 AU $\times$ 37 AU. We investigated the rotational velocities as a function of the disk radius, finding that its motions between 130 AU and 60 AU are partially fitted with a Keplerian orbit by a stellar object of $\sim 0.30\ M_\odot$, while the motions within 60 AU do not follow any Keplerian orbit at all. This makes it difficult to lead a reliable estimation of the mass of L328-IRS. Nonetheless, our ALMA observations were useful enough to well constrain the inclination angle of the outflow cavity of L328-IRS as $\sim 66^\circ$, enabling us to better determine the mass accretion rate of $\sim 8.9 \times 10^{-7}\ M_\odot\ \mathrm{yr}^{-1}$. From assumptions that the internal luminosity of L328-IRS is mostly due to this mass accretion process in the disk, or that L328-IRS has mostly accumulated the mass through this constant accretion rate during its outflow activity, its mass was estimated to be ~ 0.012–$0.023\ M_\odot$, suggesting L328-IRS to be a substellar object. However, we leave our identification of L328-IRS as a proto-brown dwarf to be tentative because of various uncertainties especially regarding the mass accretion rate.

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Why do protoplanetary disks appear not massive enough to form the known exoplanet population?

Carlo F. Manara[1], **Alessandro Morbidelli**[2] **and Tristan Guillot**[2]

[1] European Southern Observatory, Karl-Schwarzschild-Strasse 2, 85748 Garching bei München, Germany; [2] Laboratoire Lagrange, Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Boulevard de l'Observatoire, CS 34229, 06304 Nice Cedex 4, France

E-mail contact: cmanara *at* eso.org

When and how planets form in protoplanetary disks is still a topic of discussion. Exoplanet detection surveys and protoplanetary disk surveys are now providing results that allow us to have new insights. We collect the masses of confirmed exoplanets and compare their dependence with stellar mass with the same dependence for protoplanetary disk masses measured in ∼1-3 Myr old star-forming regions. The latter are recalculated by us using the new estimates of their distances derived from Gaia DR2 parallaxes. We note that single and multiple exoplanetary systems form two different populations, probably pointing to a different formation mechanism for massive giant planets around very low mass stars. While expecting that the mass in exoplanetary systems is much lower than the measured disk masses, we instead find that exoplanetary systems masses are comparable or higher than the most massive disks. This same result is found also by converting the measured planet masses into heavy-element content (core masses for the giant planets and full masses for the super-Earth systems) and by comparing this value with the disk dust masses. Unless disk dust masses are heavily underestimated, this is a big conundrum. An extremely efficient recycling of dust particles in the disk cannot solve this conundrum. This implies that either the cores of planets have formed very rapidly (<0.1-1 Myr) and large amount of gas is expelled on the same timescales from the disk, or that disks are continuously replenished of fresh planet-forming material from the environment. These hypotheses can be tested by measuring disk masses in even younger targets and by better understanding if and how the disks are replenished by their surroundings.

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ALMA observations of the young protostellar system Barnard 1b: signatures of an incipient hot corino in B1b-S

N. Marcelino[1], **M. Gerin**[2], **J. Cernicharo**[1], **A. Fuente**[3], **H.A. Wootten**[4], **E. Chapillon**[5,6], **J. Pety**[5,2], **D.C. Lis**[2], **E. Roueff**[2], **B. Commerçon**[7], **and A. Ciardi**[2]

[1] Instituto de Física Fundamental, CSIC, C/ Serrano 123, 28006 Madrid, Spain; [2] Sorbonne Université, Observatoire de Paris, Université PSL, École normale supérieure, CNRS, LERMA, F-75014, Paris, France; [3] Observatorio Astronmico Nacional (OAN,IGN), Apdo 112, E-28803 Alcal de Henares, Spain; [4] National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, USA; [5] Institut de Radioastronomie Millimétrique (IRAM), 300 rue de la Piscine, 38406 Saint Martin d'Hères, France; [6] Laboratoire d'astrophysique de Bordeaux, Univ. Bordeaux, CNRS, B18N, alle Geoffroy Saint-Hilaire, 33615 Pessac, France; [7] Univ Lyon, Ens de Lyon, Univ Lyon1, CNRS, Centre de Recherche Astrophysique de Lyon UMR5574, F-69007, Lyon, France

E-mail contact: nuria.marcelino *at* csic.es

The Barnard 1b core shows signatures of being at the earliest stages of low-mass star formation, with two extremely young and deeply embedded protostellar objects. Hence, this core is an ideal target to study the structure and chemistry of the first objects formed in the collapse of prestellar cores. We present ALMA Band 6 spectral line observations at $\sim 0''.6$ of angular resolution towards Barnard 1b. We have extracted the spectra towards both protostars, and used a Local Thermodynamic Equilibrium (LTE) model to reproduce the observed line profiles. B1b-S shows rich and complex spectra, with emission from high energy transitions of complex molecules, such as CH_3OCOH and CH_3CHO, including vibrational level transitions. We have tentatively detected for the first time in this source emission from NH_2CN, NH_2CHO, CH_3CH_2OH, CH_2OHCHO, CH_3CH_2OCOH and both aGg' and gGg' conformers of $(CH_2OH)_2$. This is the first detection of ethyl formate (CH_3CH_2OCOH) towards a low-mass star forming region. On the other hand, the spectra of the FHSC candidate B1b-N are free of COMs emission. In order to fit the observed line profiles in B1b-S, we used a source model with two components: an inner hot and compact component (200 K, $0''.35$) and an outer and colder one (60 K, $0''.6$). The resulting COM abundances in B1b-S range from 1×10^{-13} for NH_2CN and NH_2CHO, up to 1×10^{-9} for CH_3OCOH. Our ALMA Band 6 observations reveal the presence of a compact and hot

component in B1b-S, with moderate abundances of complex organics. These results indicate that a hot corino is being formed in this very young Class 0 source.

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Probing the protoplanetary disk gas surface density distribution with ^{13}CO emission

A. Miotello[1,2], S. Facchini[3], E.F. van Dishoeck[2,3], and S. Bruderer

[1] European Southern Observatory, Karl-Schwarzschild-Str 2, D-85748 Garching, Germany; [2] Leiden Observatory, Leiden University, Niels Bohrweg 2, NL-2333 CA Leiden, The Netherlands; [3] Max-Planck-institute für extraterrestrische Physik, Giessenbachstraße, D-85748 Garching, Germany

E-mail contact: amiotell *at* eso.org

It is key to constrain the gas surface density distribution, $\Sigma_{\rm gas}$, as function of disk radius in protoplanetary disks. In this work we investigate if spatially resolved observations of rarer CO isotopologues may be good tracers of $\Sigma_{\rm gas}$. Physical-chemical models with different input $\Sigma_{\rm gas}(R)$ are run. The input disk surface density profiles are compared with the simulated ^{13}CO intensity radial profiles to check if and where the two follow each other. There is always an intermediate region in the disk where the slope of the ^{13}CO radial emission profile and $\Sigma_{\rm gas}(R)$ coincide. At small radii the line radial profile underestimates $\Sigma_{\rm gas}$, as ^{13}CO emission becomes optically thick. The same happens at large radii where the column densities become too low and ^{13}CO is not able to efficiently self-shield. If the gas surface density profile is a simple power-law of the radius, the input power-law index can be retrieved within 20% uncertainty if one choses the proper radial range. If instead $\Sigma_{\rm gas}(R)$ follows the self-similar solution for a viscously evolving disk, retrieving the input power-law index becomes challenging, in particular for small disks. Nevertheless, it is found that the power-law index can be in any case reliably fitted at a given line intensity contour around 6 K km s^{-1}, and this produces a practical method to constrain the slope of $\Sigma_{\rm gas}(R)$. Application of such a method is shown in the case study of the TW Hya disk. Spatially resolved ^{13}CO line radial profiles are promising to probe the disk surface density distribution, as they directly trace $\Sigma_{\rm gas}(R)$ profile at radii well resolvable by ALMA. There, chemical processes like freeze-out and isotope selective photodissociation do not affect the emission, and, assuming that the volatile carbon does not change with radius, no chemical model is needed when interpreting the observations.

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Chemical Signatures of the FU Ori Outbursts

Tamara Molyarova[1], Vitaly Akimkin[1], Dmitry Semenov[2,3], Péter Ábrahám[4], Thomas Henning[3], Ágnes Kóspál[4,3], Eduard Vorobyov[5,6], and Dmitri Wiebe[1]

[1] Institute of Astronomy, Russian Academy of Sciences, 48 Pyatnitskaya St., Moscow, 119017, Russia; [2] Chemistry Department, Ludwig Maximilian University, Butenandtstr. 5-13, D-81377 Munich, Germany; [3] Max Planck Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany; [4] Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Konkoly-Thege Miklósút 15-17, 1121 Budapest, Hungary; [5] Department of Astrophysics, The University of Vienna, Vienna, A-1180, Austria; [6] Research Institute of Physics, Southern Federal University, Stachki 194, Rostov-on-Don, 344090, Russia

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

The FU Ori-type young stellar objects are characterized by a sudden increase in luminosity by 1–2 orders of magnitude, followed by slow return to the pre-outburst state on timescales of ∼10–100 yr. The outburst strongly affects the entire disk, changing its thermal structure and radiation field. In this paper, using a detailed physical-chemical model we study the impact of the FU Ori outburst on the disk chemical inventory. Our main goal is to identify gas-phase molecular tracers of the outburst activity that could be observed after the outburst with modern telescopes such as ALMA and NOEMA. We find that the majority of molecules experience a considerable increase in the total disk gas-phase abundances due to the outburst, mainly due to the sublimation of their ices. Their return to the pre-outburst chemical state takes different amounts of time, from nearly instantaneous to very long. Among the former ones we identify CO, NH_3, C_2H^6, C_3H_4, etc. Their abundance evolution tightly follows the luminosity curve. For CO the abundance increase does not exceed an order of magnitude, while for other tracers the abundances increase by 2–5 orders of magnitude. Other molecules like H_2CO and NH_2OH have longer retention timescales, remaining in the gas phase for ∼10–10^3 yr after the end of the outburst. Thus H_2CO could be used as an indicator of the previous outbursts in the post-outburst FU Ori systems. We investigate the corresponding time-dependent chemistry in detail and present the most favorable transitions and ALMA configurations for future observations.

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Origin of 1I/'Oumuamua. I. An ejected protoplanetary disk object?

Amaya Moro-Martin[1]

[1] Space Telescope Science Institute, 3700 San Martin Dr., Baltimore, MD 21218, USA

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

1I/'Oumuamua is the first interstellar interloper to have been detected. Because planetesimal formation and ejection of predominantly icy objects are common by-products of the star and planet formation processes, in this study we address whether 1I/'Oumuamua could be representative of this background population of ejected objects. The purpose of the study of its origin is that it could provide information about the building blocks of planets in a size range that remains elusive to observations, helping to constrain planet formation models. We compare the mass density of interstellar objects inferred from its detection to that expected from planetesimal disks under two scenarios: circumstellar disks around single stars and wide binaries, and circumbinary disks around tight binaries. Our study makes use of a detailed study of the PanSTARRS survey volume; takes into account that the contribution from each star to the population of interstellar planetesimals depends on stellar mass, binarity, and planet presence; and explores a wide range of possible size distributions for the ejected planetesimals, based on solar system models and observations of its small-body population. We find that 1I/'Oumuamua is unlikely to be representative of a population of isotropically distributed objects, favoring the scenario that it originated from the planetesimal disk of a young nearby star whose remnants are highly anisotropic. Finally, we compare the fluxes of meteorites and micrometeorites observed on Earth to those inferred from this population of interstellar objects, concluding that it is unlikely that one of these objects is already part of the collected meteorite samples.

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Gap Formation in Planetesimal Disks Via Divergently Migrating Planets

Sarah J. Morrison[1], **Kaitlin M. Kratter**[2]

[1] School of Physics and Astronomy, Queen Mary University of London, Mile End Road, London E1 4NS, UK; [2] School of Physics & Astronomy, University of Leeds, Leeds LS2 9JT, UK; [3] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK; [4] Centro de Astrobiología (CSIC/INTA), Ctra. de Torrejón a Ajalvir km 4, 28850, Torrejón de Ardoz, Spain; [5] SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, UK; [6] St Andrews Centre for Exoplanet Science, University of St Andrews, St Andrews KY16 9SS, UK; [7] Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK; [8] SUPA, Institute for Astronomy, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, UK; [9] Centre for Exoplanet Science, University of Edinburgh, Edinburgh EH9 3HJ, UK

E-mail contact: smorrison *at* psu.edu

While many observed debris disks are thought to have gaps suggestive of the presence of planets, direct imaging surveys do not find many high mass planets in these systems. We investigate if divergent migration is a viable mechanism for forming gaps in young debris disks with planets of low enough mass to currently elude detection. We perform numerical integrations of planet pairs embedded in planetesimal disks to assess the conditions for which divergent, planetesimal-driven migration occurs and gaps form within the disk. Gap widths and the migration rate of planets within a pair depend on both disk mass and the degree to which the planets share disk material. We find that planet pairs with planets more massive than Neptune can produce gaps with widths similar to their orbit distance within 10 Myr at orbit separations probed by direct imaging campaigns. Pairs of migrating super-Earths likely cannot form

observable gaps on the same time and distance scales, however. Inferring the responsible planet masses from these gaps while neglecting migration could overestimate the mass of planets by more than an order of magnitude.

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Role of environment and gas temperature in the formation of multiple protostellar systems: molecular tracers

Nadia M. Murillo[1], Ewine F. van Dishoeck[1,2], John J. Tobin[3], Joseph C. Mottram[4] and Agata Karska[5]

[1] Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA, Leiden, the Netherlands; [2] Max-Planck-Institut für extraterrestrische Physik, Giessenbachstrasse 1, 85748, Garching bei Munich, Germany; [3] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, 440 W. Brooks Street, Norman, Oklahoma 73019, USA; [4] Max Planck Institute for Astronomy, Königstuhl 17, 69117, Heidelberg, Germany; [5] Centre for Astronomy, Nicolaus Copernicus University, Faculty of Physics, Astronomy and Informatics, Grudziadzka 5, 87100, Torun, Poland

E-mail contact: nmurillo *at* gmail.com

Context: Simulations suggest that gas heating due to radiative feedback is a key factor in whether or not multiple protostellar systems will form. Chemistry is a good tracer of the physical structure of a protostellar system, since it depends on the temperature structure.
Aims: We aim to study the relationship between envelope gas temperature and protostellar multiplicity.
Methods: Single dish observations of various molecules that trace the cold, warm and UV-irradiated gas are used to probe the temperature structure of multiple and single protostellar systems on 7000 AU scales.
Results: Single, close binary, and wide multiples present similar current envelope gas temperatures, as estimated from H_2CO and DCO^+ line ratios. The temperature of the outflow cavity, traced by c-C_3H_2, on the other hand, shows a relation with bolometric luminosity and an anti-correlation with envelope mass. Although the envelope gas temperatures are similar for all objects surveyed, wide multiples tend to exhibit a more massive reservoir of cold gas compared to close binary and single protostars.
Conclusions: Although the sample of protostellar systems is small, the results suggest that gas temperature may not have a strong impact on fragmentation. We propose that mass, and density, may instead be key factors in fragmentation.

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Radiation Hydrodynamics Simulations of Photoevaporation of Protoplanetary Disks. II. Metallicity Dependence of UV and X-Ray Photoevaporation

Riouhei Nakatani[1], Takashi Hosokawa[2], Naoki Yoshida[1,3,4], Hideko Nomura[5] and Rolf Kuiper[6]

[1] Department of Physics, School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan; [2] Department of Physics, Kyoto University, Sakyo-ku, Kyoto, 606-8502, Japan; [3] Kavli Institute for the Physics and Mathematics of the Universe (WPI), UT Institute for Advanced Study, The University of Tokyo, Kashiwa, Chiba 277-8583, Japan; [4] Research Center for the Early Universe (RESCEU), School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan; [5] Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo, 152-8551, Japan; [6] Institute of Astronomy and Astrophysics, University of Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen, Germany

E-mail contact: r.nakatani *at* utap.phys.s.u-tokyo.ac.jp

We perform a suite of radiation hydrodynamics simulations of photoevaporating disks with varying the metallicity in a wide range of $10^{-3}\,Z_\odot \le Z \le 10^{0.5}\,Z_\odot$. We follow the disk evolution for over ~ 5000 years by solving hydrodynamics, radiative transfer, and non-equilibrium chemistry. Our chemistry model is updated from the first paper of this series by adding X-ray ionization and heating. We study the metallicity dependence of the disk photoevaporation rate and examine the importance of X-ray radiation. In the fiducial case with solar metallicity, including the X-ray effects does not significantly increase the photoevaporation rate when compared to the case with ultra-violet (UV) radiation only. At sub-solar metallicities in the range of $Z > 10^{-1.5}\,Z_\odot$, the photoevaporation rate increases as metallicity

decreases owing to the reduced opacity of the disk medium. The result is consistent with the observational trend that disk lifetimes are shorter in low metallicity environments. Contrastingly, the photoevaporation rate decreases at even lower metallicities of $Z \leq 10^{-1.5}\,Z_\odot$, because dust-gas collisional cooling remains efficient compared to far UV photoelectric heating whose efficiency depends on metallicity. The net cooling in the interior of the disk suppresses the photoevaporation. However, adding X-ray radiation significantly increases the photoevaporation rate, especially at $Z \sim 10^{-2}\,Z_\odot$. Although the X-ray radiation itself does not drive strong photoevaporative flows, X-rays penetrate deep into the neutral region in the disk, increase the ionization degree there, and reduce positive charges of grains. Consequently, the effect of photoelectric heating by far UV radiation is strengthened by the X-rays and enhances the disk photoevaporation.

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Evidence for Very Early Migration of the Solar System Planets from the Patroclus-Menoetius binary Jupiter Trojan

David Nesvorný[1], David Vokrouhlický[1,2], William F. Bottke[1], Harold F. Levison[1]

[1] Department of Space Studies, Southwest Research Institute, 1050 Walnut St., Suite 300, Boulder, CO, 80302, USA; [2] Institute of Astronomy, Charles University, V Holesovickách[2], CZ–18000 Prague 8, Czech Republic

E-mail contact: davidn *at* boulder.swri.edu

The orbital distribution of trans-Neptunian objects provides strong evidence for the radial migration of Neptune. The outer planets' orbits are thought to have become unstable during the early stages with Jupiter having scattering encounters with a Neptune-class planet. As a consequence, Jupiter jumped inward by a fraction of an au, as required from inner solar system constraints, and obtained its current orbital eccentricity. The timing of these events is often linked to the lunar Late Heavy Bombardment that ended ∼700 Myr after the dispersal of the protosolar nebula (t_0). Here we show instead that planetary migration started shortly after t_0. Such early migration is inferred from the survival of the Patroclus-Menoetius binary Jupiter Trojan. The binary formed at $t \lesssim t_0$ within a massive planetesimal disk once located beyond Neptune. The longer the binary stayed in the disk, the greater the likelihood that collisions would strip its components from one another. The simulations of its survival indicate that the disk had to have been dispersed by migrating planets within <100 Myr of t_0. This constraint implies that the planetary migration is unrelated to the formation of the youngest lunar basins.

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On the role of magnetic fields in star formation

C. J. Nixon[1] and J. E. Pringle[1,2]

[1] Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH, UK; [2] Institute of Astronomy, Madingley Road, Cambridge, CB3 0HA, UK

E-mail contact: cjn *at* leicester.ac.uk

Magnetic fields are observed in star forming regions. However simulations of the late stages of star formation that do not include magnetic fields provide a good fit to the properties of young stars including the initial mass function (IMF) and the multiplicity. We argue here that the simulations that do include magnetic fields are unable to capture the correct physics, in particular the high value of the magnetic Prandtl number, and the low value of the magnetic diffusivity. The artificially high (numerical and uncontrolled) magnetic diffusivity leads to a large magnetic flux pervading the star forming region. We argue further that in reality the dynamics of high magnetic Prandtl number turbulence may lead to local regions of magnetic energy dissipation through reconnection, meaning that the regions of molecular clouds which are forming stars might be essentially free of magnetic fields. Thus the simulations that ignore magnetic fields on the scales on which the properties of stellar masses, stellar multiplicities and planet-forming discs are determined, may be closer to reality than those which include magnetic fields, but can only do so in an unrealistic parameter regime.

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Very massive stars in not so massive clusters

Seungkyung Oh[1,2] and Pavel Kroupa[1,3]

[1] Helmholtz-Institut für Strahlen- und Kernphysik (HISKP), University of Bonn, Nussallee 14-16, 53115 Bonn, Germany; [2] Department of Physics and Astronomy, University of Sheffield, Hicks Building, Hounsfield Road, Sheffield S3 7RH, UK; [3] Faculty of Mathematics and Physics, Astronomical Institute, Charles University in Prague, V Holesovickách 2, CZ-180 00 Praha 8, Czech Republic

E-mail contact: s.oh *at* sheffield.ac.uk

Very young star clusters in the Milky Way exhibit a well-defined relation between their maximum stellar mass, $m_{\rm max}$, and their mass in stars, $M_{\rm ecl}$. A recent study shows that the young intermediate-mass star cluster VVV CL041 possibly hosts a >80 $M_\odot$ star, WR62-2, which appears to violate the existence of the $m_{\rm max}$–$M_{\rm ecl}$ relation since the mass of the star is almost two times higher than that expected from the relation. By performing direct N-body calculations with the same mass as the cluster VVV CL041 (3000 $M_\odot$), we study whether such a very massive star can be formed via dynamically induced stellar collisions in a binary-rich star cluster that initially follows the $m_{\rm max}$–$M_{\rm ecl}$ relation. Eight out of 100 clusters form a star more massive than 80 $M_\odot$ through multiple stellar collisions. This suggests that the VVV CL041 cluster may have become an outlier of the relation because of its early-dynamical evolution, even if the cluster followed the relation at birth. We find that more than half of our model clusters host a merger product as its most massive member within the first 5 Myr of cluster evolution. Thus, the existence of stars more massive than the $m_{\rm max}$–$M_{\rm ecl}$ relation in some young clusters is expected due to dynamical processes despite the validity of the $m_{\rm max}$–$M_{\rm ecl}$relation. We briefly discuss evolution of binary populations in our model.

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The Co-evolution of Disk and Star in Embedded Stages: The Case of the Very Low-mass Protostar

Yuki Okoda[1], Yoko Oya[1], Nami Sakai[2], Yoshimasa Watanabe[3,4], Jes K.Jørgensen[5], Ewine F. van Dishoeck[6] and Satoshi Yamamoto[1]

[1] Department of Physics, The University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan; [2] RIKEN Cluster for Pioneering Research, Wako, Saitama 351-0198, Japan; [3] Department of Physics, The University of Tsukuba, Tsukuba, Ibaraki 305-8577, Japan; [4] Tomonaga Center for the History of the Universe, Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Ibaraki 305-8571, Japan; [5] Centre for Star and Planet Formation, Niels Bohr Institute and Natural History of Denmark, University of Copenhagen, Øster Voldgade 5-7, DK-1350, Copenhagen K, Denmark; [6] Leiden Observatory, Leiden University, PO Box 9513, 2300 RA, Leiden, The Netherlands Max-Plank Institut fu?r Extrsterrestrische Physik (MPE), Giessenbachstr.1, 85748, Garching, Germany

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

We have observed the CCH ($N = 3-2, J = 7/2-5/2, F = 4-3$ and $3-2$) and SO (6_7-5_6) emission at a 0.2" angular resolution toward the low-mass Class 0 protostellar source IRAS 15398-3359 with ALMA. The CCH emission traces the infalling-rotating envelope near the protostar with the outflow cavity extended along the northeast-southwest axis. On the other hand, the SO emission has a compact distribution around the protostar. The CCH emission is relatively weak at the continuum peak position, while the SO emission has a sharp peak there. Although the maximum velocity shift of the CCH emission is about 1 km s^{-1} from the systemic velocity, a velocity shift higher than 2 km s^{-1} is seen for the SO emission. This high velocity component is most likely associated with the Keplerian rotation around the protostar. The protostellar mass is estimated to be $0.007^{+0.004}_{-0.003}$ M$_\odot$ from the velocity profile of the SO emission. With this protostellar mass, the velocity structure of the CCH emission can be explained by the model of the infalling-rotating envelope, where the radius of the centrifugal barrier is estimated to be 40 au from the comparison with the model. The disk mass evaluated from the dust continuum emission by assuming the dust temperature of 20 K–100 K is 0.1–0.9 times the stellar mass, resulting in the Toomre Q parameter of 0.4–5. Hence, the disk structure may be

partly unstable. All these results suggest that a rotationally-supported disk can be formed in the earliest stages of the protostellar evolution.

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Production of atomic hydrogen by cosmic rays in dark clouds

Marco Padovani[1], Daniele Galli[1], Alexei V. Ivlev[2], Paola Caselli[2] and Andrea Ferrara[3]

[1] INAF-Osservatorio Astrofisico di Arcetri, Firenze, Italy; [2] Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany; [3] Scuola Normale Superiore, Pisa, Italy

E-mail contact: padovani *at* arcetri.astro.it

The presence of small amounts of atomic hydrogen, detected as absorption dips in the 21 cm line spectrum, is a well-known characteristic of dark clouds. The abundance of hydrogen atoms measured in the densest regions of molecular clouds can be only explained by the dissociation of H_2 due to cosmic rays. We want to assess the role of Galactic cosmic rays in the formation of atomic hydrogen, by using recent developments in the characterisation of the low-energy spectra of cosmic rays and advances in the modelling of their propagation in molecular clouds. We model the attenuation of the interstellar cosmic rays entering a cloud and compute the dissociation rate of molecular hydrogen due to collisions with cosmic-ray protons and electrons as well as fast hydrogen atoms. We compare our results with the available observations. The cosmic-ray dissociation rate is entirely determined by secondary electrons produced in primary ionisation collisions. These secondary particles constitute the only source of atomic hydrogen at column densities above $\sim 10^{21}$ cm^{-2}. We also find that the dissociation rate decreases with column density, while the ratio between the dissociation and ionisation rates varies between about 0.6 and 0.7. From comparison with observations we conclude that a relatively flat spectrum of interstellar cosmic-ray protons, as the one suggested by the most recent Voyager 1 data, can only provide a lower bound for the observed atomic hydrogen fraction. An enhanced spectrum of low-energy protons is needed to explain most of the observations. Our findings show that a careful description of molecular hydrogen dissociation by cosmic rays can explain the abundance of atomic hydrogen in dark clouds. An accurate characterisation of this process at high densities is crucial for understanding the chemical evolution of star-forming regions.

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Evolution of spatio-kinematic structures in star-forming regions: are Friends of Friends worth knowing?

Richard J. Parker[1] and Nicholas J. Wright[2]

[1] Department of Physics and Astronomy, The University of Sheffield, Hicks Building, Hounsfield Road, Sheffield, S3 7RH, UK; [2] Astrophysics Group, Keele University, Keele, Staffordshire ST5 5BG, UK

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

The Friends of Friends algorithm identifies groups of objects with similar spatial and kinematic properties, and has recently been used extensively to quantify the distributions of gas and stars in young star-forming regions. We apply the Friends of Friends algorithm to N-body simulations of the dynamical evolution of subvirial (collapsing) and supervirial (expanding) star-forming regions. We find that the algorithm picks out a wide range of groups $(1 - 25)$ for statistically identical initial conditions, and cannot distinguish between subvirial and supervirial regions in that we obtain similar mode and median values for the number of groups it identifies. We find no correlation between the number of groups identified initially and either the initial or subsequent spatial and kinematic tracers of the regions' evolution, such as the amount of spatial substructure, dynamical mass segregation, or velocity dispersion. We therefore urge caution in using the Friends of Friends algorithm to quantify the initial conditions of star formation.

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A transitional disk around an intermediate mass star in the sparse population of the Orion OB1 Association

Alice Pérez-Blanco[1], Karina Maucó[2], Jesús Hernández[3], Nuria Calvet[4], Catherine Espaillat[5], Melissa McClure[6], Cesar Briceño[7], Connor Robinson[5], Daniel Feldman[5], Luis Villarreal[8], Paola D'Alessio[2]

[1] University of Leeds,School of Physics and Astronomy, LS29JT, Leeds, UK; [2] Instituto de Radioastronomía y Astrofísica, UNAM, Morelia, Mexico; [3] Instituto de Astronomía, UNAM, Ensenada, BC, Mexico; [4] Dept. of Astronomy, University of Michigan, 500 Church Street, Ann Arbor, MI 48109, USA; [5] Department of Astronomy, Boston University, 725 Commonwealth Avenue, Boston, MA 02215, USA; [6] Anton Pannekoek Institute for Astronomy, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands; [7] Cerro Tololo Interamerican Observatory, Casilla 603, la Serena, Chile; [8] Postgrado de Física Fundamental, Universidad de Los Andes, Mérida, Venezuela

E-mail contact: hernandj *at* astro.unam.mx

We present a detailed study of the disk around the intermediate mass star SO 411, aiming to explain the spectral energy distribution of this star. We show that this is a transitional disk truncated at ∼11 au, with ∼0.03 lunar masses of optically thin dust inside the cavity. Gas also flows through the cavity, since we find that the disk is still accreting mass onto the star, at a rate of $\sim 5 \times 10^{-9}$ $M_\odot$ yr^{-1}. Until now, SO 411 has been thought to belong to the ∼3 Myr old σ Orionis cluster. However, we analyzed the second Gaia Data Release in combination with kinematic data previously reported, and found that SO 411 can be associated with an sparse stellar population located in front of the σ Orionis cluster. If this is the case, then SO 411 is older and even more peculiar, since primordial disks in this stellar mass range are scarce for ages >5 Myr. Analysis of the silicate 10 μm feature of SO 411 indicates that the observed feature arises at the edge of the outer disk, and displays a very high crystallinity ratio of ∼0.5, with forsterite the most abundant silicate crystal. The high forsterite abundance points to crystal formation in non-equilibrium conditions. The PAH spectrum of SO 411 is consistent with this intermediate state between the hot and luminous Herbig Ae and the less massive and cooler T Tauri stars. Analysis of the 7.7 μm PAH feature indicates that small PAHs still remain in the SO 411 disk.

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Constraining the nature of DG Tau A's thermal and non-thermal radio emission

S. J. D. Purser[1], R. E. Ainsworth[1,2], T. P. Ray[1], D. A. Green[3], A. M. Taylor[1,4] and A. M. M. Scaife[2]

[1] School of Cosmic Physics, Dublin Institute for Advanced Studies, 31 Fitzwilliam Place, Dublin 2, Ireland; [2] Jodrell Bank Centre for Astrophysics, Alan Turing Building, School of Physics and Astronomy, University of Manchester, Oxford Road, Manchester, M13 9PL, United Kingdom; [3] Astrophysics Group, Cavendish Laboratory, 19 J. J. Thomson Avenue, Cambridge CB3 0HE; [4] DESY, Platanenallee 6, D-15738 Zeuthen, Germany

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

DG Tau A, a class-II young stellar object (YSO) displays both thermal, and non-thermal, radio emission associated with its bipolar jet. To investigate the nature of this emission, we present sensitive ($\sigma \sim 2$ μJy beam^{-1}), Karl G. Jansky Very Large Array (VLA) 6 and 10 GHz observations. Over 3.81yr, no proper motion is observed towards the non-thermal radio knot C, previously thought to be a bowshock. Its quasi-static nature, spatially-resolved variability and offset from the central jet axis supports a scenario whereby it is instead a stationary shock driven into the surrounding medium by the jet. Towards the internal working surface, knot A, we derive an inclination-corrected, absolute velocity of 258 ± 23 km s^{-1}. DG Tau A's receding counterjet displays a spatially-resolved increase in flux density, indicating a variable mass loss event, the first time such an event has been observed in the counterjet. For this ejection, we measure an ionised mass loss rate of $(3.7 \pm 1.0) \times 10^{-8} \mathrm{M}_\odot \mathrm{yr}^{-1}$ during the event. A contemporaneous ejection in the approaching jet isn't seen, showing it to be an asymmetric process. Finally, using radiative transfer modelling, we find that the extent of the radio emission can only be explained with the presence of shocks, and therefore reionisation, in the flow. Our modelling highlights the need to consider the relative angular size of optically thick, and thin, radio emission from a jet, to the synthesised beam, when deriving its physical conditions from its spectral index.

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The Fate Of Formamide In A Fragmenting Protoplanetary Disc

David Quenard[1], John D. Ilee[2,3], Izaskun Jimenez-Serra[4,1], Duncan H. Forgan[5,6], Cassandra Hall[7] and Ken Rice[8,9]

[1] School of Physics and Astronomy, Queen Mary University of London, Mile End Road, London E1 4NS, UK; [2] School of Physics & Astronomy, University of Leeds, Leeds LS2 9JT, UK; [3] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK; [4] Centro de Astrobiologia (CSIC/INTA), Ctra. de Torrejon a Ajalvir km 4, 28850, Torrejon de Ardoz, Spain; [5] SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews KY16 9SS, UK; [6] St Andrews Centre for Exoplanet Science, University of St Andrews, St Andrews KY16 9SS, UK; [7] epartment of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK; [8] SUPA, Institute for Astronomy, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, UK; [9] Centre for Exoplanet Science, University of Edinburgh, Edinburgh EH9 3HJ, UK

E-mail contact: j.d.ilee *at* leeds.ac.uk

Recent high-sensitivity observations carried out with ALMA have revealed the presence of complex organic molecules (COMs) such as methyl cyanide (CH_3CN) and methanol (CH_3OH) in relatively evolved protoplanetary discs. The behaviour and abundance of COMs in earlier phases of disc evolution remains unclear. Here we combine a smoothed particle hydrodynamics simulation of a fragmenting, gravitationally unstable disc with a gas-grain chemical code. We use this to investigate the evolution of formamide (NH_2CHO), a pre-biotic species, in both the disc and in the fragments that form within it. Our results show that formamide remains frozen onto grains in the majority of the disc where the temperatures are <100 K, with a predicted solid-phase abundance that matches those observed in comets. Formamide is present in the gas-phase in three fragments as a result of the high temperatures ($\geq$200 K), but remains in the solid-phase in one colder ($\leq$150 K) fragment. The timescale over which this occurs is comparable to the dust sedimentation timescales, suggesting that any rocky core which is formed would inherit their formamide content directly from the protosolar nebula.

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Chemical tracers in proto-brown dwarfs: CN, HCN, and HNC observations

B. Riaz[1], W.-F. Thi[2] and P. Caselli[2]

[1] Universitäts-Sternwarte München, Scheinerstrae 1, D-81679 Mnchen, Germany; [2] Max Planck Institut fur Extraterrestrial Physics, Germany

E-mail contact: basriaz *at* gmail.com

We present results from a study of nitrogen chemistry in Class 0/I proto-brown dwarfs (proto-BDs). We have used the IRAM 30 m telescope to observe the CN (2-1), HCN (3-2), and HNC (3-2) lines in 7 proto-BDs. All proto-BDs show a large CN/HCN abundance ratio of ¿20, and a HNC/HCN abundance ratio close to or larger than unity. The enhanced CN/HCN ratios can be explained by high UV flux originating from an active accretion zone in the proto-BDs. The larger than unity HNC/HCN ratio for the proto-BDs is likely caused by a combination of low temperature and high density. Both CN and HNC show a flat distribution with CO, indicating that these species can survive in regions where CO is depleted. We have investigated the correlations in the molecular abundances of these species for the proto-BDs with Class 0/I protostars. We find tentative trends of CN (HCN) abundances being about an order of magnitude higher (lower) in the proto-BDs compared to protostars. HNC for the proto-BDs shows a nearly constant abundance unlike the large spread of 2 orders of magnitude seen for the protostars. Also notable is a rise in the HNC/HCN abundance ratio for the lowest luminosity objects, suggesting that this ratio is higher under low-temperature environments. None of the relatively evolved Class Flat/Class II brown dwarfs in our sample show emission in HNC. The HNC molecule can be considered as an efficient tracer to search and identify early stage sub-stellar mass objects.

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Exploring the Origins of Earth's Nitrogen: Astronomical Observations of Nitrogen-bearing Organics in Protostellar Environments

Thomas Sean Rice[1], Edwin A. Bergin[1], Jes K. Jørgensen[2] and S. F. Wampfler[3]

[1] University of Michigan Department of Astronomy 311 West Hall, 1085 South University Avenue, Ann Arbor, MI 48109, USA; [2] Centre for Star and Planet Formation, Niels Bohr Institute & Natural History Museum of Denmark, University of Copenhagen, Øster Voldgade 5-7, 1350, Copenhagen K., Denmark; [3] Center for Space and Habitability, University of Bern, Gesellschaftsstrasse 6, CH-3012 Bern, Switzerland

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

It is not known whether the original carriers of Earth's nitrogen were molecular ices or refractory dust. To investigate this question, we have used data and results of *Herschel* observations towards two protostellar sources: the high-mass hot core of Orion KL, and the low-mass protostar IRAS 16293-2422. Towards Orion KL, our analysis of the molecular inventory of Crockett et al. indicates that HCN is the organic molecule that contains by far the most nitrogen, carrying $74^{+5}_{-9}\%$ of nitrogen-in-organics. Following this evidence, we explore HCN towards IRAS 16293-2422, which we consider a solar analog. Towards IRAS 16293-2422, we have reduced and analyzed *Herschel* spectra of HCN, and fit these observations against "jump" abundance models of IRAS 16293-2422's protostellar envelope. We find an inner-envelope HCN abundance $X_{\rm in} = 5.9 \pm 0.7 \times 10^{-8}$ and an outer-envelope HCN abundance $X_{\rm out} = 1.3 \pm 0.1 \times 10^{-9}$. We also find the sublimation temperature of HCN to be $T_{\rm jump} = 71 \pm 3$ K; this measured $T_{\rm jump}$ enables us to predict an HCN binding energy $E_{\rm B}/k = 3840 \pm 140$ K. Based on a comparison of the HCN/H2O ratio in these protostars to N/H2O ratios in comets, we find that HCN (and, by extension, other organics) in these protostars is incapable of providing the total bulk N/H2O in comets. We suggest that refractory dust, not molecular ices, was the bulk provider of nitrogen to comets. However, interstellar dust is not known to have 15N enrichment, while high 15N enrichment is seen in both nitrogen-bearing ices and in cometary nitrogen. This may indicate that these 15N-enriched ices were an important contributor to the nitrogen in planetesimals and likely to the Earth.

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Evolution of circumbinary protoplanetary disks with photoevaporative winds driven by External Far Ultraviolet Radiation

M. Shadmehri[1], S.M. Ghoreyshi[1,2], N. Alipour[1]

[1] Department of Physics, Faculty of Science, Golestan University, Gorgan 49138-15739, Iran; [2] Research Institute for Astronomy and Astrophysics of Maragha (RIAAM), Maragha, P.O. Box: 55134-441, Iran

E-mail contact: m.shadmehri *at* gu.ac.ir

Lifetimes of protoplanetary disks (PPDs) are believed to be severely constrained by material depleting mechanisms, including photoevaporative winds due to the host star radiation or external radiation sources. Most previous studies focused on exploring the role of the winds in the exposed PPDs with a single star; however, exploring the evolution of the circumbinary disks with the photoevaporative winds driven by the host star radiation and external radiation sources deserves further investigation. In this study, we investigate the evolution of the circumbinary PPDs with the photoevaporative winds induced by external far ultraviolet (FUV) radiation field. We show that this mass-loss process can significantly constrain properties of a circumbinary PPD, including its lifetime, mass and radius. The lifetime of a circumbinary PPD, for instance, is found by a factor of about two longer than a similar circumstellar disk and this enhancement strongly depends on the viscosity parameter. But our model shows that viscosity dependence of the disk lifetime in the circumbinary case is more pronounced compared to the circumstellar case. We also show that dispersal of a circumbinary PPD occurs over a longer time as the disk temperature distribution becomes steeper. Our results also imply that dead zone in a photoevaporative circumbinary PPD extends over a larger radial range in comparison to a circumstellar disk counterpart. We also show that our calculations are in agreement with the observed circumbinary PPDs orbiting equal-mass binaries.

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Cluster formation in the W40 and Serpens South complex triggered by the expanding HII region

Tomomi Shimoikura[1], Kazuhito Dobashi[1], Fumitaka Nakamura[2], Yoshito Shimajiri[3] and Koji Sugitani[4]

[1] Tokyo Gakugei University, Japan; [2] National Astronomical Observatory of Japan; [3] Laboratoire AIM, CEA/DSM-CNRS-Universite Paris Diderot, France; [4] Nagoya City University, Japan

E-mail contact: ikura *at* u-gakugei.ac.jp

We present results of the mapping observations covering a large area of 1 square degree around W40 and Serpens South carried out in the ^{12}CO ($J = 1-0$), ^{13}CO ($J = 1-0$), C^{18}O ($J = 1-0$), CCS (J_N=$8_7 - 7_6$), and N_2H^+ ($J = 1-0$) emission lines with the 45 m Nobeyama Radio Telescope. W40 is a blistered HII region, and Serpens South is an infrared dark cloud accompanied by a young cluster. The relationship between these two regions which are separated by $\sim 20'$ on the sky has not been clear so far. We found that the C^{18}O emission is distributed smoothly throughout the W40 and Serpens South regions, and it seems that the two regions are physically connected. We divided the C^{18}O emission into four groups in terms of the spatial distributions around the HII region which we call 5, 6, 7, and 8 km s^{-1} components according to their typical LSR velocities, and propose a three-dimensional model of the W40 and Serpens South complex. We found two elliptical structures in position-velocity diagrams, which can be explained as a part of two expanding shells. One of the shells is the small inner shell just around the HII region, and the other is the large outer shell corresponding to the boundary of the HII region. Dense gas associated with the young cluster of Serpens South is likely to be located at the surface of the outer shell, indicating that the natal clump of the young cluster is interacting with the outer shell being compressed by the expansion of the shell. We suggest that the expansion of the shell induced the formation of the young cluster.

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Follow-up Imaging of Disk Candidates from the Disk Detective Citizen Science Project: New Discoveries and False-Positives in WISE Circumstellar Disk Surveys

Steven M. Silverberg[1,2], Marc J. Kuchner[2], John P. Wisniewski[1], Alissa S. Bans[3], John H. Debes[4], Scott J. Kenyon[5], Christoph Baranec[6], Reed Riddle[7], Nicholas Law[8], Johanna K. Teske[9], Emily Burns-Kaurin[10], Milton K.D. Bosch[10], Tadeas Cernohous[10], Katharina Doll[10], Hugo A. Durantini Luca[10], Michiharu Hyogo[10], Joshua Hamilton[10], Johanna J.S. Finnemann[10], Lily Lau[10] and The Disk Detective Collaboration[11]

[1] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, 440 W. Brooks Street, Norman, OK 73019, USA; [2] NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, Code 667, Greenbelt, MD 20771, USA; [3] Department of Physics, Emory University, 201 Dowman Drive, Atlanta, GA 30322, USA; [4] Space Telescope Science Instiitute, 3700 San Martin Dr., Baltimore, MD 21218, USA; [5] Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138, USA; [6] Institute for Astronomy, University of Hawai'i at Manoa, Hilo, HI 96720-2700, USA; [7] Department of Physics, Mathematics, and Astronomy, California Institute of Technology, Pasadena, CA 91125, USA; [8] Department of Physics and Astronomy, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3255, USA; [9] Carnegie DTM, 5231 Broad Branch Road, NW, Washington, DC 20015, USA; [10] Disk Detective Advanced User Team; [11] https://www.diskdetective.org/#/authors

E-mail contact: silverberg *at* ou.edu

The Disk Detective citizen science project aims to find new stars with excess 22-μm emission from circumstellar dust in the AllWISE data release from the Wide-field Infrared Survey Explorer (WISE). We evaluated 261 Disk Detective objects of interest with imaging with the Robo-AO adaptive optics instrument on the 1.5m telescope at Palomar Observatory and with RetroCam on the 2.5m du Pont telescope at Las Campanas Observatory to search for background objects at $0.15'' - 12''$ separations from each target. Our analysis of these data lead us to reject 7% of targets. Combining this result with statistics from our online image classification efforts implies that at most 7.9% $\pm$ 0.2% of AllWISE-selected infrared excesses are good disk candidates. Applying our false positive rates to other surveys, we find that the infrared excess searches of McDonald et al. (2012), McDonald et al. (2017), and Marton et al. (2016) all have false positive rates $> 70\%$. Moreover, we find that all thirteen disk candidates in Theissen & West (2014) with W4 signal-to-noise > 3 are false positives. We present 244 disk candidates that have survived vetting by follow-up

imaging. Of these, 213 are newly-identified disk systems. Twelve of these are candidate members of comoving pairs based on *Gaia* astrometry, supporting the hypothesis that warm dust is associated with binary systems. We also note the discovery of 22 μm excess around two known members of the Scorpius-Centaurus association, and identify known disk host WISEA J164540.79-310226.6 as a likely Sco-Cen member. Thirty-one of these disk candidates are closer than $\sim$ 125 pc (including 27 debris disks), making them good targets for direct imaging exoplanet searches.

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Chemical Diversity in Three Massive Young Stellar Objects associated with 6.7 GHz CH_3OH Masers

Kotomi Taniguchi[1,2,3], Masao Saito[3,1], Liton Majumdar[4], Tomomi Shimoikura[5], Kazuhito Dobashi[5], Hiroyuki Ozeki[6], Fumitaka Nakamura[3,1], Tomoya Hirota[3,1], Tetsuhiro Minamidani[2,1], Yusuke Miyamoto[2,3] and Hiroyuki Kaneko[2]

[1] Department of Astronomical Science, School of Physical Science, SOKENDAI (The Graduate University for Advanced Studies), Osawa, Mitaka, Tokyo 181-8588, Japan; [2] Nobeyama Radio Observatory, National Astronomical Observatory of Japan, Minamimaki, Minamisaku, Nagano 384-1305, Japan; [3] National Astronomical Observatory of Japan, Osawa, Mitaka, Tokyo 181-8588, Japan; [4] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA; [5] Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Nukuikitamachi, Koganei, Tokyo 184-8501, Japan; [6] Department of Environmental Science, Faculty of Science, Toho University, Miyama, Funabashi, Chiba 274-8510, Japan

E-mail contact: kotomi.taniguchi4043 *at* gmail.com

We have carried out observations in the 42−46 and 82−103 GHz bands with the Nobeyama 45-m radio telescope, and in the 338.2−339.2 and 348.45−349.45 GHz bands with the ASTE 10-m telescope toward three high-mass star-forming regions containing massive young stellar objects (MYSOs), G12.89+0.49, G16.86−2.16, and G28.28−0.36. We have detected HC_3N including its ^{13}C and D isotopologues, CH_3OH, CH_3CCH, and several complex organic molecules (COMs). Combining our previous results of HC_5N in these sources, we compare the $N(HC_5N)/N(CH_3OH)$ ratios in the three observed sources. The ratio in G28.28−0.36 is derived to be $0.091^{+0.109}_{-0.039}$, which is higher than that in G12.89+0.49 by one order of magnitude, and that in G16.86−2.16 by a factor of ~ 5. We investigate the relationship between the $N(HC_5N)/N(CH_3OH)$ ratio and the $N(CH_3CCH)/N(CH_3OH)$ ratio. The relationships of the two column density ratios in G28.28−0.36 and G16.86−2.16 are similar to each other, while HC_5N is less abundant when compared to CH_3CCH in G12.89+0.49. These results imply a chemical diversity in the lukewarm ($T \sim 20 - 30$ K) envelope around MYSOs. Besides, several spectral lines from complex organic molecules, including very-high-excitation energy lines, have been detected toward G12.89+0.49, while the line density is significantly low in G28.28−0.36. These results suggest that organic-poor MYSOs are surrounded by a carbon-chain-rich lukewarm envelope (G28.28−0.36), while organic-rich MYSOs, namely hot cores, are surrounded by a CH_3OH-rich lukewarm envelope (G12.89+0.49 and G16.86−2.16).

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Interferometric Observations of Cyanopolyynes toward the G28.28−0.36 High-Mass Star-Forming Region

Kotomi Taniguchi[1], Yusuke Miyamoto[1], Masao Saito[1,2], Patricio Sanhueza[1], Tomomi Shimoikura[3], Kazuhito Dobashi[3], Fumitaka Nakamura[1,2] and Hiroyuki Ozeki[4]

[1] National Astronomical Observatory of Japan, Osawa, Mitaka, Tokyo 181-8588, Japan; [2] Department of Astronomical Science, School of Physical Science, SOKENDAI (The Graduate University for Advanced Studies), Osawa, Mitaka, Tokyo 181-8588, Japan; [3] Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Nukuikitamachi, Koganei, Tokyo 184-8501, Japan; [4] Department of Environmental Science, Faculty of Science, Toho University, Miyama, Funabashi, Chiba 274-8510, Japan

E-mail contact: kotomi.taniguchi4043 *at* gmail.com

We have carried out interferometric observations of cyanopolyynes, HC_3N, HC_5N, and HC_7N, in the 36 GHz band toward the G28.28−0.36 high-mass star-forming region using the Karl G. Jansky Very Large Array (VLA) Ka-band receiver. The spatial distributions of HC_3N and HC_5N are obtained. HC_5N emission is coincident with a 450 μm dust continuum emission and this clump with a diameter of ~ 0.2 pc is located at the east position from the 6.7 GHz methanol maser by ~ 0.15 pc. HC_7N is tentatively detected toward the clump. The HC_3N : HC_5N : HC_7N column density ratios are estimated at $1.0 : \sim 0.3 : \sim 0.2$ at an HC_7N peak position. We discuss possible natures of the 450 μm continuum clump associated with the cyanopolyynes. The 450 μm continuum clump seems to contain deeply embedded low- or intermediate-mass protostellar cores, and the most possible formation mechanism of the cyanopolyynes is the warm carbon chain chemistry (WCCC) mechanism. In addition, HC_3N and compact HC_5N emission is detected at the edge of the 4.5 μm emission, which possibly implies that such emission is the shock origin.

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Photometric variability of massive young stellar objects. I.

G. D. C. Teixeira[1,2], M.S.N. Kumar[1,3], L. Smith[4,3], P. W. Lucas[3], C. Morris[3], J. Borissova[5,6], M. J. P. F. G. Monteiro[1,2], A. Caratti o Garatti[7], C. Contreras Peña[8], D. Froebrich[9] and J.F. Gameiro[1,2]

[1] Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto, CAUP, Rua das Estrelas, 4150-762 Porto, Portugal; [2] Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, Rua do Campo Alegre 687, PT4169-007 Porto, Portugal; [3] Centre for Astrophysics Research, University of Hertfordshire, Hatfield, AL10 AB, UK; [4] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK; [5] Instituto de Fisica y Astronomía, Universidad de Valparaíso, Gran Bretaña 1111, Playa Ancha, Valparaíso, Chile; [6] Millennium Institute of Astrophysics, Vicuña Mackenna 4860, 7820436 Macul, Santiago, Chile; [7] Dublin Institute for Advanced Studies, Astronomy & Astrophysics Section, 31 Fitzwilliam Place, Dublin 2, Ireland; [8] Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter, Devon EX4 4SB, UK; [9] Centre for Astrophysics and Planetary Science, School of Physical Sciences, University of Kent, Canterbury, CT2 7NH, UK

E-mail contact: gteixeira *at* astro.up.pt

The Vista Variables in the Via Lactea (VVV) survey has allowed for an unprecedented number of multi-epoch observations of the southern Galactic plane. In a recent paper, 13 massive young stellar objects (MYSOs) have already been identified within the highly variable ($\Delta K_s > 1$ mag) YSO sample of another published work. This study aims to understand the general nature of variability in MYSOs. Here we present the first systematic study of variability in a large sample of candidate MYSOs. We examined the data for variability of the putative driving sources of all known Spitzer extended green objects (EGOs) (270) and bright 24 μm sources coinciding with the peak of 870 μm detected ATLASGAL clumps (448), a total of 718 targets. Of these, 190 point sources (139 EGOs and 51 non-EGOs) displayed variability ($IQR > 0.05$, $\Delta K_s > 0.15$ mag). 111 and 79 light-curves were classified as periodic and aperiodic respectively. Light-curves have been sub-classified into eruptive, dipper, fader, short-term-variable and long-period-variable-YSO categories. Lomb-Scargle periodogram analysis of periodic light-curves was carried out. 1 - 870 μm spectral energy distributions of all the variable sources were fitted with YSO models to obtain the representative properties of the variable sources. 41% of the variable sources are represented by > 4 M$_\odot$ objects, and only 6% were modelled as > 8 M$_\odot$ objects. The highest-mass objects are mostly non-EGOs, and deeply embedded, as indicated by nearly twice the extinction when compared with EGO sources. By placing them on the HR diagram we show that most of the lower mass, EGO type objects are concentrated on the putative birth-line position, while the luminous non-EGO type objects group around the zero-age-main-sequence track. Some of the most luminous far infrared (FIR) sources in the massive clumps and infrared quiet driving sources of EGOs have been missed out by this study owing to an uniform sample selection method. A high rate of detectable variability in EGO targets (139 out of 153 searched) implies that near-infrared variability in MYSOs is closely linked to the accretion phenomenon and outflow activity.

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The VLA/ALMA Nascent Disk and Multiplicity (VANDAM) Survey of Perseus Protostars. VI. Characterizing the Formation Mechanism for Close Multiple Systems

John J. Tobin[1,2,3], Leslie W. Looney[4], Zhi-Yun Li[5], Sarah I. Sadavoy[6], Michael M. Dunham[7,6], Dominique Segura-Cox[4], Kaitlin Kratter[8], Claire J. Chandler[9], Carl Melis[10], Robert J. Harris[4], and Laura Perez[11]

[1] Current address: National Radio Astronomy Observatory, 520 Edgemont Rd., Charlottesville, VA 22903, USA; [2] Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, 440 W. Brooks Street, Norman, OK 73019, USA; [3] Leiden Observatory, Leiden University, P.O. Box 9513, 2300-RA Leiden, The Netherlands; [4] Department of Astronomy, University of Illinois, Urbana, IL 61801; [5] Department of Astronomy, University of Virginia, Charlottesville, VA 22903; [6] Harvard-Smithsonian Center for Astrophysics, 60 Garden St, MS 78, Cambridge, MA 02138; [7] Department of Physics, State University of New York Fredonia, Fredonia, New York 14063, USA; [8] University of Arizona, Steward Observatory, Tucson, AZ 85721; [9] National Radio Astronomy Observatory, P.O. Box O, Socorro, NM 87801; [10] Center for Astrophysics and Space Sciences, University of California, San Diego, CA 92093; [11] Departamento de Astronomía, Universidad de Chile, Camino El Observatorio 1515, Las Condes, Santiago, Chile

E-mail contact: jjtobin *at* gmail.com

We present Atacama Large Millimeter/submillimeter Array (ALMA) observations of multiple protostar systems in the Perseus molecular cloud previously detected by the Karl G. Jansky Very Large Array (VLA). We observed 17 close (<600 AU separation) multiple systems at 1.3 mm in continuum and five molecular lines (i.e., ^{12}CO, $C^{18}O$, ^{13}CO, H_2CO, SO) to characterize the circum-multiple environments in which these systems are forming. We detect at least one component in the continuum for the 17 multiple systems. In three systems, one companion is not detected, and for two systems the companions are unresolved at our observed resolution. We also detect circum-multiple dust emission toward 8 out of 9 Class 0 multiples. Circum-multiple dust emission is not detected toward any of the 8 Class I multiples. Twelve systems are detected in the dense gas tracers toward their disks/inner envelopes. For these 12 systems, we use the dense gas observations to characterize their formation mechanism. The velocity gradients in the circum-multiple gas are clearly orthogonal to the outflow directions in 8 out of the 12 systems, consistent with disk fragmentation. Moreover, only two systems with separations <200 AU are *inconsistent* with disk fragmentation, in addition to the two widest systems (>500 AU). Our results suggest that disk fragmentation via gravitational instability is an important formation mechanism for close multiple systems, but further statistics are needed to better determine the relative fraction formed via this method.

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EPIC 203868608: A low-mass quadruple star system in the Upper Scorpius OB association

Ji Wang[1,2], Trevor J. David[1,3], Lynne Hillenbrand[1], Dimitri Mawet[1], Simon Albrecht[4], and Zibo Liu[5]

[1] Department of Astronomy, California Institute of Technology, MC 249-17, 1200 E. California Blv, Pasadena, CA 91106 USA; [2] Department of Astronomy, The Ohio State University, 100 W 18th Ave, Columbus, OH 43210 USA; [3] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA; [4] Stellar Astrophysics Centre, Department of Physics and Astronomy Aarhus University, Ny Munkegade 120, 8000, Aarhus C, Denmark; [5] Department of Astronomy & Key Laboratory of Modern Astronomy and Astrophysics in Ministry of Education, Nanjing University, 210093, China

E-mail contact: ji.wang *at* caltech.edu

Young multiple star systems provide excellent testing grounds for theories of star formation and evolution. EPIC 203868608 was previously studied (David et al. 2016) as a triple star system in the Upper Scorpius OB association, but the follow-up Keck NIRC2/HIRES/NIRSPAO observations reported here reveal its quadruple nature. We find that the system consists of a double-lined spectroscopic binary (SB2) Aab (M5+M5) and an eclipsing binary (EB) Bab with a total mass that is lower than that of the SB2. Furthermore, we measure the obliquity of the EB using the Doppler tomography technique during the primary eclipse. EPIC 203868608 Bab is likely on an inclined orbit with a projected obliquity of -57^{+40}_{-36} degrees. The inclined orbit is used to constrain the tidal quality factor for low-mass stars and the evolution of the quadruple system. The analytic framework to infer obliquity that has been developed

in this paper can be applied to other EB systems as well as transiting planets.

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Hall effect-driven formation of gravitationally unstable discs in magnetized molecular cloud cores

James Wurster[1], Matthew R Bate[1] and Daniel J Price[2]

[1] School of Physics and Astronomy, University of Exeter, Stocker Rd, Exeter EX4 4QL, UK; [2] Monash Centre for Astrophysics and School of Physics and Astronomy, Monash University, Vic 3800, Australia

E-mail contact: j.wurster *at* exeter.ac.uk

We demonstrate the formation of gravitationally unstable discs in magnetized molecular cloud cores with initial mass-to-flux ratios of five times the critical value, effectively solving the magnetic braking catastrophe. We model the gravitational collapse through to the formation of the stellar core, using Ohmic resistivity, ambipolar diffusion and the Hall effect, and using the canonical cosmic ray ionization rate of $\zeta_{CR} = 10^{-17}$ s^{-1}. When the magnetic field and rotation axis are initially aligned, $a \lesssim 1$ au disc forms after the first core phase, whereas when they are anti-aligned, a gravitationally unstable 25 au disc forms during the first core phase. The aligned model launches a 3 km s^{-1} first core outflow, while the anti-aligned model launches only a weak $\lesssim 0.3$ km s^{-1} first core outflow. Qualitatively, we find that models with $\zeta_{CR} = 10^{-17}$ s^{-1} are similar to purely hydrodynamical models if the rotation axis and magnetic field are initially anti-aligned, whereas they are qualitatively similar to ideal magnetohydrodynamical models if initially aligned.

Accepted by Monthly Notices of the Royal Astronomical Society

http://adsabs.harvard.edu/pdf/2018MNRAS.480.4434W
http://arxiv.org/pdf/1808.04376

On the origin of magnetic fields in stars

James Wurster[1], Matthew R Bate[1] and Daniel J Price[2]

[1] School of Physics and Astronomy, University of Exeter, Stocker Rd, Exeter EX4 4QL, UK; [2] Monash Centre for Astrophysics and School of Physics and Astronomy, Monash University, Vic 3800, Australia

E-mail contact: j.wurster *at* exeter.ac.uk

Are the kG-strength magnetic fields observed in young stars a fossil field left over from their formation or are they generated by a dynamo? We use radiation non-ideal magnetohydrodynamics simulations of the gravitational collapse of a rotating, magnetized molecular cloud core over 17 orders of magnitude in density, past the first hydrostatic core to the formation of the second, stellar core, to examine the fossil field hypothesis. Whereas in previous work we found that magnetic fields in excess of 10 kG can be implanted in stars at birth, this assumed ideal magnetohydrodynamics (MHD), i.e. that the gas is coupled to the magnetic field. Here we present non-ideal MHD calculations which include Ohmic resistivity, ambipolar diffusion and the Hall effect. For realistic cosmic ray ionization rates, we find that magnetic field strengths of $\lesssim$ kG are implanted in the stellar core at birth, ruling out a strong fossil field. While these results remain sensitive to resolution, they cautiously provide evidence against a fossil field origin for stellar magnetic fields, suggesting instead that magnetic fields in stars originate in a dynamo process.

Accepted by MNRAS

http://adsabs.harvard.edu/pdf/2018MNRAS.481.2450W
http://arxiv.org/pdf/1809.01234

ALMA reveals a collision between protostellar outflows in BHR 71

Luis A. Zapata[1], **Manuel Fernández-López**[2], **Luis F. Rodrıguez**[1], **Guido Garay**[3], **Satoko Takahashi**[4], **Chin-Fei Lee**[5], **and Antonio Hernández-Gómez**[1,6]

[1] Instituto de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, P.O. Box 3-72, 58090, Morelia, Michoacán, México; [2] Instituto Argentino de Radioastronomía (CCT-La Plata, CONICET; CICPBA), C.C. No. 5, 1894, Villa Elisa, Buenos Aires, Argentina; [3] Departamento de Astronomía, Universidad de Chile, Camino el Observatorio 1515, Santiago, Chile; [4] Joint ALMA Observatory, Alonso de Cordova 3108, Vitacura, Santiago, Chile; [5] Academia Sinica Institute of Astronomy and Astrophysics, P.O. Box 23-141, Taipei 106, Taiwan; [6] IRAP, Université de Toulouse, CNRS, UPS, CNES, Toulouse, France

E-mail contact: lzapata@irya.unam.mx

For a binary protostellar outflow system in which its members are located close to each other (the separation being smaller than the addition of the widths of the flows) and with large opening angles, the collision seems unavoidable regardless of the orientation of the outflows. This is in contrast to the current observational evidence of just a few regions with indications of colliding outflows, which could also suggests that the average distance between protostars is larger than the width of the flows. Here, using sensitive observations of the Atacama Large Millimeter/Submillimeter Array (ALMA), we report resolved images of carbon monoxide (CO) towards the binary flows associated with the BHR 71 protostellar system. These images reveal for the first time solid evidence that their flows are partially colliding, increasing the brightness of the CO, the dispersion of the velocities in the interaction zone, and changing part of the orientation in one of the flows. Additionally, this impact opened the possibility of knowing the 3D geometry of the system, revealing that one of its components (IRS 2) should be closer to us.

Accepted by The Astronomical Journal

https://arxiv.org/pdf/1804.00625

Abstract submission deadline

The deadline for submitting abstracts and other submissions is the first day of the month.

Dissertation Abstracts

Pulsed Accretion in Eccentric Binaries: An Observational Study of the Photometric and Kinematic Variability of Accretion in Short-Period, Pre-main Sequence Binary Stars

Benjamin Tofflemire

University of Wisconsin - Madison, USA

Department of Astronomy, 2515 Speedway, Stop C1400, Austin, TX 78712

Electronic mail: tofflemire *at* utexas.edu

Ph.D dissertation directed by: Prof. Robert Mathieu

Ph.D degree awarded: July 2018

Over the past thirty years, a detailed picture of star formation has emerged that highlights the significance of the interaction between a pre-main sequence star and its protoplanetary disk. This star-disk interaction has been extensively characterized in the case of single stars, revealing implications for pre-main sequence stellar evolution and planet formation. Many stars, however, form in binary or higher-order systems where orbital dynamics fundamentally alter this star-disk interaction. Divergence from the single-star paradigm is most extreme in the case of short-period binaries where orbital resonances are capable of clearing out disk material on size scale of the binary separation. Under these conditions, streams of material driven by the binary orbit are predicted to periodically cross this cleared gap, linking a circumbinary disk to the inner binary. These streams may feed circumstellar disks or accrete directly onto the stars themselves, leading to bursts of accretion during each orbital period.

In this thesis, I observationally characterize the binary-disk interaction in two short-period, eccentric systems, DQ Tau and TWA 3A. This is achieved through long-term monitoring campaigns that combine multiple observational probes of stellar accretion. For each source a time-series, optical photometry campaign provides a foundation for this work by measuring accretion diagnostics ∼20 times per orbit for ∼10 orbital periods. For DQ Tau, these data are supplemented with stretches of high-cadence, optical photometry that capture the detailed morphology of accretion events. In the case of TWA 3A, the addition of time-series, high-resolution optical spectroscopy provides a new lens on the kinematics of the stellar accretion flows.

The results of these campaigns reveal an intimate link between stellar accretion and the binary orbit. Both systems exhibit consistent bursts of accretion near their periastron passages that are in reasonable agreement with the predictions of numerical simulations. With the addition of kinematic information via spectroscopy, circumbinary accretion flows are found to preferentially feed the TWA 3A primary star. This is in contrast to the prediction of most numerical simulations and may point to the importance of secular interactions between the binary potential and the circumbinary disk. With the three observational studies presented in this thesis I provide a comprehensive characterization of binary accretion in eccentric systems. These results mark a significant step forward in our understanding of the binary-disk interaction and carry implications for star and planet formation in the binary environment.

https://tofflemire.github.io/local_files/Tofflemire_Thesis_Final.pdf

New Jobs

Chalmers Cosmic Origins Postdoctoral Fellowships

Applications are invited for several postdoctoral fellowships at Chalmers University of Technology (Gothenburg, Sweden) and partner institutes as part of the Chalmers Initiative on Cosmic Origins (CICO):

1) Chalmers Cosmic Origins Fellowship: One or more positions are 3-year fellowships at Chalmers;

2) Chalmers-MPIA Cosmic Origins Fellowship: One fellowship is part of the Chalmers-MPIA fellowship that is a 4-year position, shared between Chalmers (2 years) and Max-Planck-Inst. for Astronomy in Heidelberg, Germany (2 years);

3) Chalmers-UVA Cosmic Origins Fellowship: One fellowship (funding pending) is part of the Chalmers-UVA fellowship that is a 4-year position, shared between Chalmers (2 years) and Dept. of Astronomy, Univ. of Virginia, Charlottesville, VA, USA (2 years);

4) Chalmers-MPE Cosmic Origins Fellowship: One fellowship (funding pending) is part of the Chalmers-MPE fellowship that is a 4-year position, shared between Chalmers (2 years) and the Center for Astrochemical Studies at the Max-Planck-Institute for Extraterrestrial Physics (MPE) (Garching, Germany) (2 years).

A successful applicant will lead an ambitious, independent research program related to Cosmic Origins science, expected to align with the wide range of research at Chalmers and partner institutes. Relevant themes include galaxy formation evolution, ISM, astrochemistry, star cluster formation, high- and low-mass star formation, astrochemistry, and planet formation evolution, from both theoretical observational perspectives. See www.cosmicorigins.space for more information. The fellow is expected to participate in departmental activities, and promote collaboration between CICO and its partner institutes.

Included Benefits:

A competitive salary and benefits package is offered at Chalmers. Fellows are eligible for social security benefits, including health insurance, paid leave, and retirement benefits. The position also includes travel funds and opportunities for dissemination, networking, and international collaboration will be available.

Deadline: 5th December 2018

Contact: Prof. Jonathan C. Tan; Asst. Prof. Jouni Kainulainen

CICO URL: http://cosmicorigins.space/

Application URL:

http://www.chalmers.se/en/about-chalmers/Working-at-Chalmers/Vacancies/Pages/default.aspx?rmpage=job&rmjob=6

Postdoctoral Position in Star Formation Studies

Applications are invited for a two-year postdoctoral position in star formation studies at The University of Western Ontario. The successful applicant will work with Prof. Shantanu Basu, and experience with computational simulations of present-day star formation or first stars in the universe is preferred.

The applications will be assessed based on the synergy of possible research, and the selected application will also be nominated for a CITA National Fellowship to be held at Western. To apply, please send a cover letter, a cv including a publication list, and a brief description of research experience and interests, to basu@uwo.ca. The application deadline is 31 October 2018.

A description of ongoing research projects in the group and a list of recent publications can be obtained from http://physics.uwo.ca/~basu/

Meetings

New Quests in Stellar Astrophysics IV. Astrochemistry, astrobiology and the origin of life

March, 31st - April 5, 2019 - Puerto Vallarta, Mexico

Topics:

- Chemical networks in star formation to form complex (prebiotic) molecules, deuterium enrichment.
- Astrochemistry of young and mature star+disk systems.
- Prospects for exoplanet characterization: detection methods, observational probes, multi-wavelength observations and the search for biomarkers.
- Exoplanetary theoretical models: interiors, magnetic fields, atmospheres, geochemistry.
- Habitability of exo-worlds: space weather, time domain, dynamics and chemistry.
- Scenarios on the emergence of life on Earth.
- Space exploration and observations from the ground of solar system objects of astrobiological interest (Rosetta, Cassini, IRAM, ALMA, GTM, JWST, WSO, etc.).
- Historical, societal aspects and education in astrobiology.

Web site: http://www.inaoep.mx/puerto19/

Workshop on Polarization in Protoplanetary Disks and Jets

May 20-24, 2019 - Sant Cugat del Vallès, Catalonia – Spain

The study of the formation and evolution of protoplanetary disks around young stars saw a tremendous boost by the advent of ALMA and the development of new capabilities in the infrared and radio telescopes, thanks to the huge combined improvement in sensitivity, angular resolution, and image fidelity. However, the role of magnetic fields in the formation and evolution of disks around young stars is still a poorly understood topic. Are protoplanetary disks and protostellar jets magnetized? Polarimetric observations are the primary means to obtain information regarding the magnetic fields. However, this technique can be hampered by other polarization mechanisms such as dust self-scattering, radiation alignment of aspherical grains or anisotropic resonant scattering of linear polarization of molecular lines. The main goal of this focused meeting is to bring together observers and theoreticians interested in the study of magnetic fields in protoplanetary disks and protostellar jets as well as polarization mechanisms to review the current state of the research and explore effective means to probe magnetic fields.

Confirmed Invited Speakers: Carlos Carrasco-González, Benoît Comenrçon, Paulo Cortes, Christian Fendt, Martin Houde, Akimasa Kataoka, Anaëlle Maury, Ya-Wen Tang, Zhaohuan Zhu

https://sites.google.com/view/sant-cugat-forum-astrophysics/next-session

Important Dates (tentative):
Open Abstract submission: October 1st, 2018
Open Registration and payment: October 31st, 2018

The number of participants is limited to about 70

The Scientific Organizing Committee: Maria Teresa Beltran, Gemma Busquet, Jean Francois Donati, Josep Miquel Girart, Shih-Ping Lai, Aina Palau, Mayra Osorio, Wouter Vlemmings, Qizhou Zhang

Celebrating 40 Years of Alexander Tielens' Contribution to Science: The Physics and Chemistry of the ISM

September 2 – 6, 2019 in Avignon, France

Xander Tielens has been driving research in the fields of interstellar physics and chemistry and the cosmic cycle of matter with outstanding contributions for 40 years. With this meeting, we wish to celebrate his scientific achievements and discuss future research directions opened up by his contributions.

The meeting will focus on the fields strongly influenced by Xander involving the physical and chemical processes that control the interstellar medium and its life cycle: PDRs, interstellar and circumstellar dust, PAHs, ices and astrochemistry. We will especially emphasize future opportunities offered by the powerful telescopes at our disposal such as, for example, ALMA, SOFIA, and JWST.

The meeting will consist of invited reviews, invited and contributed talks, and posters. The second announcement will be made in December 2018.

Location: Centre International de Congres du Palais des Papes, Avignon, France (http://www.avignon-congres.com/)

Scientific Organizing Committee:

Cecilia Ceccarelli (chair),
Alessandra Candian (co-chair),
Jan Cami,
Carsten Dominik,
Liv Hornekaer,
Kay Justtanont,
Els Peeters,
Mark Wolfire

Local Organizing Committee:

Bertrand Lefloch (chair)

Summary of Upcoming Meetings

Planet Formation and Evolution
27 February - 1 March, Rostock, Germany
http://pfe2019.stat.physik.uni-rostock.de

New Quests in Stellar Astrophysocs IV. Astrochemistry, astrobiology and the Orign of Life
31 March - 5 April 2019, Puerto Vallarta, mexico
http://www.inaoep.mx/puerto19

Exploring the Infrared Universe: The Promise of SPICA
20 - 23 May 2019, Crete, Greece
http://www.spica2019.org

Workshop on Polarization in Protoplanetary Disks and Jets
20 - 24 May 2019, Sant Cugat del Vallès, Catalonia, Spain
http://sites.google.com/view/sant-cugat-forum-astrophysics/next-session

Zooming in on Star Formation - A tribute to Åke Nordlund
9 - 14 June 2019, Nafplio, Greece
http://www.nbia.dk/nbia-zoomstarform-2019

From Stars to Planets II: Connecting our Understanding of Star and Planet Formation
17 - 20 June 2019, Gothenburg, Sweden
http://cosmicorigins.space/fstpii

Passings

John A. Graham
1939-2018

Carnegie astronomer John Graham who also served during different periods as both Vice President and Secretary of the American Astronomical Society died at home in Washington, D.C., September 13 after a battle with brain cancer. He was 79.

Graham, who specialized in the observation of young stars and the star formation process in the Milky Way and neighboring galaxies, joined Carnegie's Department of Terrestrial Magnetism from the Cerro Tololo Inter-American Observatory in 1985. George Preston, who was Director of the Carnegie Observatories at the time Graham came to DTM, also offered Graham a simultaneous five-year adjunct appointment at the Mount Wilson and Las Campanas observatories.

'John was a passionate observer with very broad scientific interests,' said Francois Schweizer, Carnegie astronomer emeritus and longtime colleague of Graham's at both CTIO and DTM. 'But perhaps best of all, one could discuss with him any subject in astronomy and learn from his well-informed opinions. Such discussions were always permeated by his sense of humor and, hence, most enjoyable.'

In addition to his own research, Graham was an enthusiastic participant in the larger astronomy community. He was Vice President of the AAS between 1984 and 1986 and, after his retirement from DTM, he served again as the AAS Secretary from 2003 to 2009. He also spent a year as the Program Director of Stellar Astronomy and Astrophysics at the National Science Foundation's Division of Astronomical Sciences from 2000 to 2001.

Although his work at DTM focused on young stars, before coming to Carnegie he pursued knowledge of old stars in the Milky Way and Magellanic Clouds. Graham's paper on the radio galaxy NGC 5128, or Centaurus A, is still cited today. Often described as a consummate team player, he worked to establish a widely used network of photometric standard stars, as well as on the Hubble Space Telescope team with former-Observatories Director Wendy Freedman.

'John was a formal, quiet, generous, gentleman,' said DTM Director Richard Carlson. 'It was an honor to have known and worked with someone who contributed so much to Carnegie and to his field.'

[Carnegie obituary notice]

See the interview with John Graham in Star Formation Newsletter No. 250 on page 3.