THE STAR FORMATION NEWSLETTER

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

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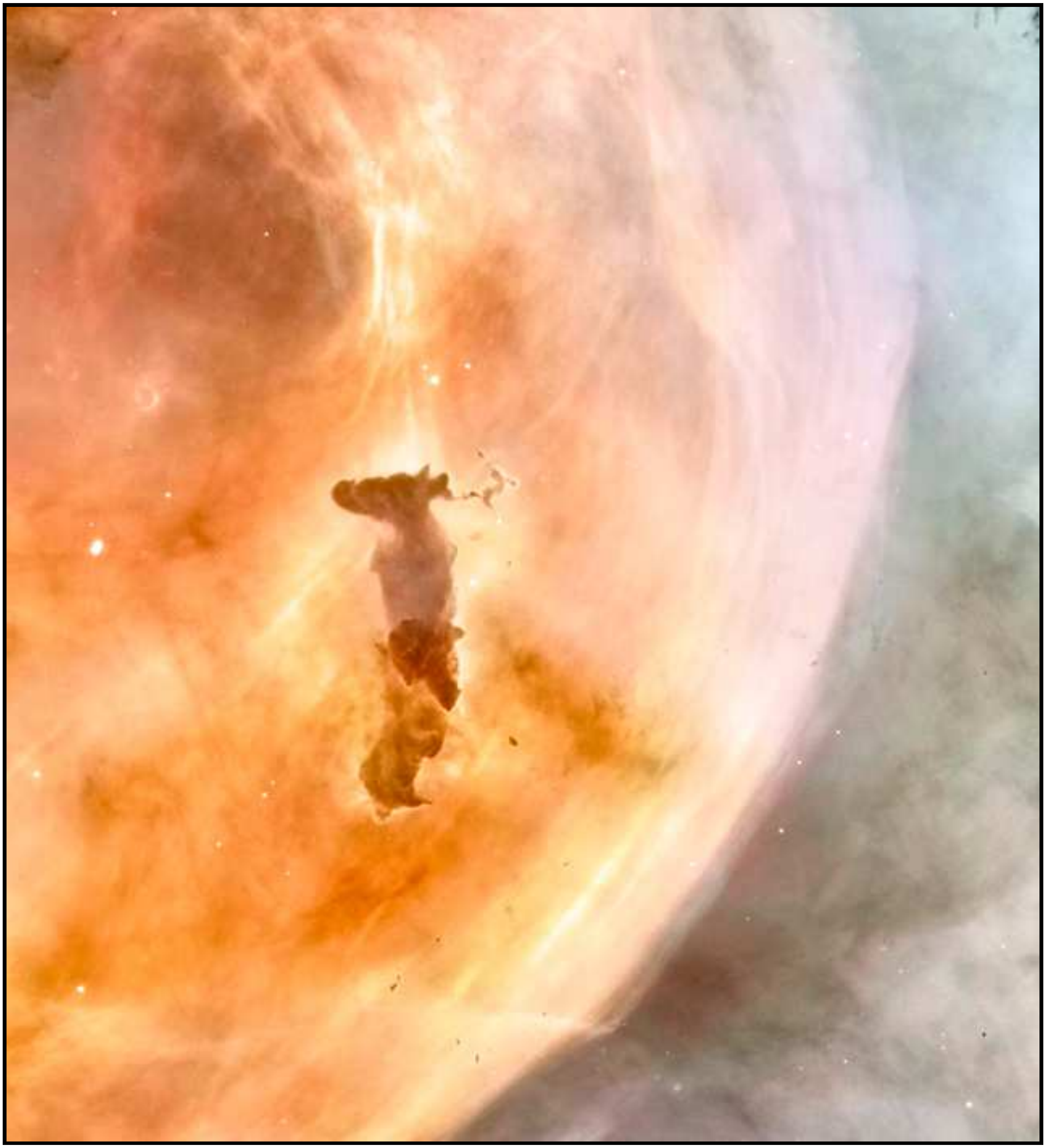

The Star Formation Newsletter

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

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Cover Picture

A photoevaporating globule is floating in the Carina Nebula in front of a giant bow shock traversing the HII region. Image obtained with the Hubble Space Telescope.

Image courtesy NASA, ESA, and N. Smith and the Hubble Heritage Team.

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

Paul Ho

in conversation with Bo Reipurth

Q: *What was your thesis about?*

A: My thesis supervisor was Alan Barrett, an early pioneer in radio astronomy who was first to explain the greenhouse effect on Venus, and who also discovered the OH molecule in interstellar space. The successful detection of OH essentially started the field of molecular radio astronomy. The detection of the important molecules of water and ammonia quickly followed in the late 1960s by the Charlie Townes group at Berkeley, which in turn led to an explosion in detections of many molecular species in space. Barrett studied microwave spectroscopy under Townes at Columbia. Hence it was no accident that these discoveries came during that time. When I started my Ph.D. studies in 1972, observations of the ammonia molecule became possible with the development of the traveling wave maser receiver at the MIT Haystack Observatory. To explore the utility of the cm-wave transitions of ammonia in the interstellar medium became the topic of my thesis. As in many cases in experimental physics, the availability of a new generation of instruments with increased sensitivity made it possible to work at the frontiers. My thesis was made possible by (1) the 37m Haystack telescope being developed by the air force, (2) the construction of a sensitive receiver system, (3) the development of a digital correlator, and (4) the discovery of a molecular transition which fits into the spectral window of the instruments.

Q: *In 1983 you published an Annual Reviews article on 'Interstellar Ammonia' with Charles Townes.*

A: In 1979, I moved to Berkeley on a Miller Fellowship. By then, we had already made quite a bit of progress in the study of ammonia, detecting the lines not only in the Galaxy, but also in external galaxies. The availability of closely spaced transitions in the centimeter wavelengths made this molecule an important tool for measuring gas temperatures. Moreover, with the newly constructed VLA, imaging of the ammonia emission can be accomplished with the resolution of an arc second, making it the best spectroscopic tool for molecular line studies at high angular resolution. When I got to Berkeley, I thought it would be a good time to summarize the field of interstellar ammonia with Charlie Townes, the original discoverer of this molecule in interstellar space.

Q: *One of your early interests were molecular clouds associated with HII regions, a subject you explored in a series of papers. What did you learn?*

A: The study of molecular clouds associated with HII regions was driven by sensitivity. Aubrey Haschick, who taught me interferometry, and I found that for the most compact HII regions, they were still embedded in the original molecular cloud cores from which the stars had formed. This meant that the surrounding cloud material were at relatively high density, having condensed as they must have via gravitational collapse. The newly formed stars driving the HII regions also provided heating to the surrounding molecular matter. The higher density and higher temperatures meant that the molecular lines would be brighter and therefore easier to study, especially with higher angular resolution via interferometry. These early studies allowed us to see that massive stars often formed in clusters, and their impact on the surrounding material can be detected. Hence, energetics, dynamics, could be studied as a function of evolution within the star formation process.

Q: *You were among the first to study the molecular structure and dynamics in regions with outflow activity.*

A: In the late 1970's, the star formation process as we understand today was not yet elucidated. Herbig-Haro (H-H) objects were not yet recognized as an ejection phenomenon. Proper motions and shock signatures from molecular hydrogen were key clues to the nature of the H-H objects. At that epoch, water masers were also being studied with VLBI techniques, and proper motion studies were also revealing that these were outflowing material. While large velocity wings were seen in practically the first spectrum of CO towards Orion, they were not recognized as an important dynamical signature. Two important sources were then studied, L1551 and Cepheus A, where the red-shifted and blue-shifted CO emission were found to be separated in space and bipolar in appearance. The work on Cepheus A was led by our good friend, Luis Rodriguez, who was a graduate student at Harvard while I was a graduate student at MIT. We shared the Haystack telescope most of the time, and we began to collaborate on these studies of outflows in CO. We were actually pursuing GGD (Gyulbudaghian, Glushkov, and Denisyuk) objects, thought to be like H-H objects. We were making studies in water masers, ammonia, and carbon monoxide, and we found the large velocity wings. The recognition that CO/molecular outflows were an important part of the star formation process came later, when it was found to be an ubiquitous phenomenon associated always with young star formation. Of course, then we followed up with lots of other studies, including radio continuum to study the exciting stars where we found the radio continuum jets, and dynamical studies of the molecular cores and the outflows.

Q: *You have been deeply involved with the SubMillimeter Array. What do you see as its mission in the ALMA era?*

A: We built the SMA in order to get closer to the peak of the radiation curve. For the cold interstellar medium, the submillimeter wavelengths are the closest we can get to the radiation peak from the ground. Further more, we expected an abundance of molecular lines because of the Einstein A coefficient which scales with the third power of frequency. The rarer molecular transitions can be detected much better in the submillimeter. ALMA has now been completed. It has tremendously more sensitivity than the SMA. However, the smaller telescopes of the SMA mean that a wider field is sampled at once. If we add multi-pixel receivers and sample a wider bandwidth on the backend, then, we are increasing the amount of photons which we can sample at any one time. This will compensate for the smaller collecting area, and thereby provide an effectively faster instrument. In the era of larger aperture telescopes, the smaller telescopes should always concentrate on wide-field imaging science. That is where the SMA will be focused in the future. And of course we must do preparatory work before going to ALMA. And there is also the northern sky which is not sampled by ALMA. The SMA being located in Hawaii is also very important from the point of view of VLBI science. Cross correlating the SMA with ALMA is very important for the Event Horizon Telescope. We will also cross correlate the SMA with the Greenland Telescope which we are deploying.

Q: *Another major project you have worked on is AMiBA.*

A: The AMiBA was the first international project to be led by the ASIAA, and is also the first and only instrument dedicated to cosmological studies in Asia and in Hawaii. It served as a driver for the development of ASIAA in the last decade, in cultivating an engineering group and a cosmology group. Its scientific output has been in the study of galaxy clusters via the SZE. For pointed observations of clusters, AMiBA has performed well. However, for large scale blind surveys of large swaths of the sky, and for CMB studies, the later generations of bolometric instruments are definitely superior in speed. AMiBA has served the ASIAA very well, and has been responsible for our subsequent engagement on ALMA, and has also helped launch the optical astronomical instrumentation program at the ASIAA. The AMiBA and optical developments were a coordinated program in cosmology and particle astrophysics, as a collaboration between ASIAA and the universities in Taiwan. This program was initiated by Fred Lo of ASIAA (who went on to become NRAO director) and Pauchy Hwang of NTU as a collaboration between our two groups.

Q: *You have just stepped down after a decade as head of ASIAA. What gave you most satisfaction?*

A: No doubt the greatest satisfaction has been to support the growth of the group of young astronomers and physicists and engineers now working at ASIAA and at the universities in Taiwan. These young people have done very well by all forms of metrics. This has come about from the generous support of the Academia Sinica, the Ministry of Education, and the National Science Council (now the Ministry of Science and Technology). We also had a lot of support and help from collaborators all over the world. Astronomy is now a healthy discipline in Taiwan, and we expect continuous support from the government.

Q: *As the new Director General of the East Asian Observatory, what are your aspirations and challenges?*

A: We all know that ESO is the strongest astronomical organization in the world. They have been able to combine the resources and personnel in Europe to pursue excellence in large scale astronomical projects. In Asia, we hope to be able to do the same, in being able to combine our resources and expertise. EAO, a project of NAOC, NAOJ, ASIAA, and KASI, hopes to combine and coordinate our efforts, and leverage our existing projects, in order to build large frontier projects in the future. Astronomical facilities are now very expensive, and no region can really build them on their own resources. ESO is a fine example on how to build consensus and how to pursue joint projects. EAO will aim to do the same.

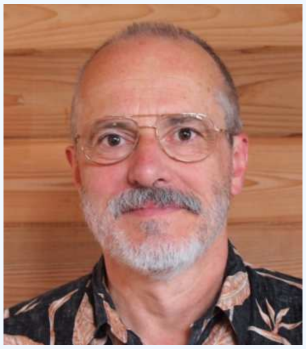
Q: *You are now planning to go to Greenland. Why?*

A: We are working on deploying the Greenland Telescope, or GLT, to the summit of Greenland. We have been retrofitting the ALMA-NA prototype 12m telescope for operations under polar conditions. The site was selected for the fine atmospheric conditions in order to support submillimeter operations for VLBI. The site together with ALMA will provide a really long intercontinental baseline. In particular, at submillimeter wavelengths, an angular resolution on the order of 20 micro arc seconds will be achieved. The South Pole Telescope, together with the SMA and JCMT and ALMA, will aim to resolve the shadow of SMBH SgrA* in the Galactic Center. The GLT together with SMA and JCMT and ALMA, will aim to resolve the shadow of M87 SMBH. Also, M87 has a jet emanating from the SMBH and we aim to image the base of the jet. During the times that we are not doing VLBI, we will be pursuing THz spectroscopy. The GLT will be the first arctic observatory, and will have the highest angular resolution in astronomy when submm VLBI is successfully executed. We are looking forward to that.

My Favorite Object

SVS 13: An Eruptive Source with a Precessing Outflow

Klaus W. Hodapp



Discovery and Early Observations

The NGC 1333 reflection nebula associated with the L1450 dark cloud in Perseus contains an extremely young cluster, where many stars are currently forming. For a general overview of the NGC 1333 star-forming region and a review of the literature on the SVS 13 sub-cluster, the reader is referred to the review article by Walawender et al. (2008) and reminded of the beautiful picture of NGC 1333 on the title page of *The Star Formation Newsletter 264* of December 2014. Within this star-forming region, one particularly interesting object is the infrared source SVS 13, identified by Strom, Vrba, & Strom (1976) on infrared photometric scans. Just prior to that, Herbig (1974) had found the group of Herbig-Haro (HH) objects 7–11 that quite obviously trace a collimated outflow with axis at P.A. $\approx 123°$ emanating from a dense molecular core that turned out to coincide, within positional uncertainties, with SVS 13. This attracted the attention of radio astronomers leading to the discovery of a bipolar CO outflow associated with the HH 7–11 optical HH objects by Snell & Edwards (1981).

While for many years the distance to NGC 1333 adopted by Herbig & Jones (1983) of 350 pc was commonly used, the distance to NGC 1333 SVS 13 has now been quite firmly established by the VLBI parallax measurements of Hirota et al. (2008) of masers associated with this object: 235 ± 18 pc, which is consistent with the photometric distance measured by Cernis (1990) of 220 pc.

I personally became interested in SVS 13 when I studied the near-infrared polarization of young stellar objects associated with bipolar mass outflow for my thesis project (Hodapp, 1984) at the Max-Planck Institute for Astronomy in Heidelberg. The goal of this work was to find observational evidence in support of the idea proposed by Elsässer & Staude (1978) that the high degrees of infrared polarization found in some young stellar objects were due to scattering in the lobes of a bipolar nebula while direct unpolarized light from the central star was strongly obscured by an edge-on disk. Objects with mapped bipolar CO outflow, chains of HH objects, or an imaged jet formed the basis of my sample, taking any of these signposts of outflow as an indication of the orientation of a spatially unresolved bipolar nebula and its equatorial disk. SVS 13 had two of these features, a mapped CO outflow and the chain of Herbig-Haro objects, and was therefore included in my small sample.

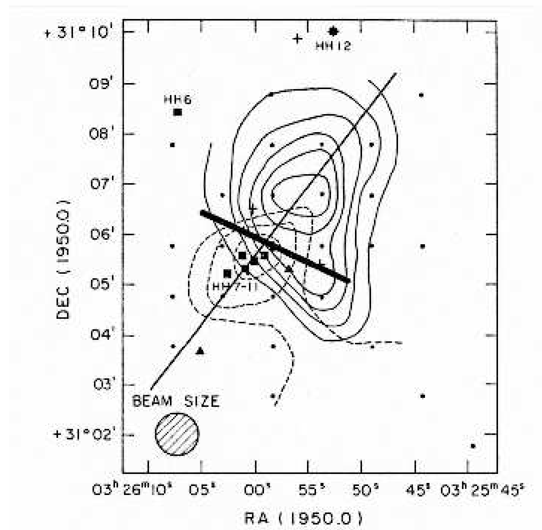


Figure 1: SVS13 *K*-band polarization vector, from Hodapp (1984), superposed on the CO outflow map of Snell & Edwards (1981)

The *K*-band polarization that I measured was 6.9% at an angle of 65°, close enough to perpendicular to both the axis of the CO map and the axis of the HH 7–11 chain to strongly suggest scattering as the origin of the polarization. The less than precise alignment of the polarization angle with the outflow axis already hints at a more complicated spatial structure of the outflowing material.

Zooming in on the SVS 13 Outflow

Emission from shock-excited H_2 in the 1–0 S(1) line was first detected in the HH 7–11 system by Simon & Joyce (1983). With the advent of infrared imaging cameras, the emission from the SVS 13 region was studied with rapidly improving sensitivity and spatial resolution. Aspin, Sandell, & Russel (1994) obtained the first deep K-band image of the region, and Hodapp & Ladd (1995) published a deep image of the H_2 1–0 S(1) emission throughout much of the southern part of the NGC 1333 cluster, showing that there are numerous objects producing H_2 jets and shocks, giving the impression of outflows crisscrossing each other. The SVS 13 outflow appears relatively poorly collimated and is comprised of a number of individual shock fronts, as can be seen in Fig. 2 that presents a progression from seeing-limited to diffraction-limited images of the SVS 13 outflow. The two lower panels demonstrate that a series of bubbles in the SVS 13 outflow originate very close to the near-infrared and optically visible star SVS 13, and that there is a morphological connection between these small-scale bubbles and the larger scale structure of the flow further downwind. It is also clear from this comparison that different parts of the SVS 13 outflow, emitted at different times, are propagating in different directions.

Not included in the H_2 emission images in Fig. 2, but prominent in the temporal sequence of high spatial resolution color-composite images of Fig. 4, is the presently active, 0.″2 long [FeII] jet and its faint extension into the S(1) bubble, all oriented at P.A. 145° from SVS 13. Two older bubbles, visible in the 100 mas image of Fig. 2, are lying more to the south of SVS 13 at P.A. 159°, indicating some variations in the outflow direction. In contrast, the main chain of Herbig-Haro knots HH 7-11 lies at P.A. 123° (Davis et al. (2001).

While at optical wavelengths, the SVS 13 outflow manifests itself only in the Herbig-Haro chain HH 7-11 (Herbig & Jones, 1983), longer wavelengths increasingly reveal a counterflow that appears anti-parallel to the HH 7–11 axis, is laterally displaced from that axis, and appears in general fainter and less organized (Fig. 2, top panel). Based on Spitzer telescope images over a time span of 7 years, Raga et al. (2013) have obtained one proper motion data point for a relatively well defined knot in that counterflow, and this one point is consistent with the counterflow originating from SVS 13. Also, no other embedded protostar has been detected by Walsh et al. (2007) to the north of SVS 13 that could alternatively explain this flow as being independent from SVS 13. The displacement in the outflow axis, in combination with the recent changes in outflow direction reported by Hodapp & Chini (2014), adds to the evidence that the source of the SVS 13 outflow is changing direction, probably due to some precessing motion in a binary system. As an explanation for the differences between the HH 7–11 flow and the counterflow, Walsh et al. (2007) have suggested that the northern counterflow enters into the central cavity of NGC 1333, resulting in different ambient pressure and excitation conditions than the HH 7–11 flow.

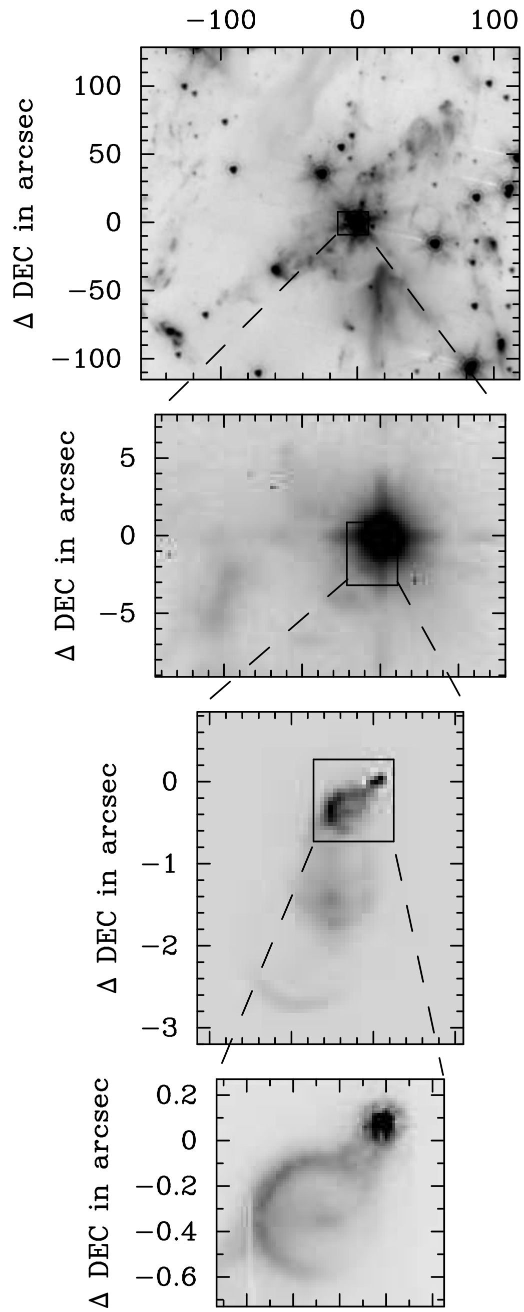


Figure 2: The SVS 13 outflow at four different spatial scales: The top image is a Spitzer channel 2 (4.5 μm) image based on the same original data as those used by Raga et al. (2013) for their proper motion study. The second panel from the top is a small portion of a ground-based H_2 S(1) 2.122 μm image. The third and fourth panel, both OSIRIS line images from Hodapp & Chini (2014), show the integrated H_2 S(1) line intensity observed with the 100 mas spaxel scale and with the 20 mas spaxel scale, respectively.

The SVS 13 Sub-Cluster

SVS 13 is a member of a small cluster of very young stars, located to the south of the somewhat more developed NGC 1333 reflection nebula. Multiple outflows detectable by their shock-excited H_2 emission criss-cross this region, and radio observations have found a few even more deeply embedded objects. Within this very active star-forming region, SVS 13 appears to be member of a small, dense sub-group of protostars. The cm and mm wave radio source closest to the near-infrared object SVS 13 is VLA 4, which Rodriguez (1999) found to be a binary source with $0.''3$ separation. A comparison by Hodapp & Chini (2014) of the 2MASS catalog position (Skrutskie et al. 2006) that is based on observations in 1999 with the radio positions of Anglada, Rodríguez, & Torrelles (2000) at 3.6 cm and of Anglada et al. (2004) at 7 mm (Fig. 3) obtained at epochs before and after the 2MASS measurements demonstrates that the near-infrared position coincides very closely with the position of the radio source VLA 4B. Of the two components of the VLA 4 binary, source B is associated with more dust than source A, and this better matches SVS 13 being the source of an on-going outflow.

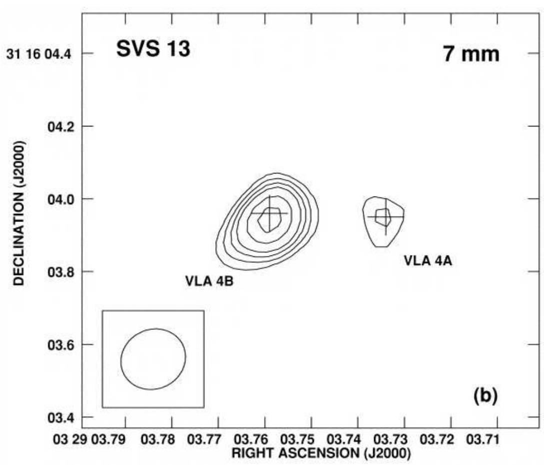


Figure 3: VLA 7 mm map of the VLA 4 binary radio source from Anglada et al. (2004)

SVS 13, an Eruptive Variable

SVS 13 experienced a sudden increase in brightness around 1990, as first reported by Mauron & Thouvenot (1991) and further studied by Eislöffel et al. (1991), Liseau, Lorenzetti, & Molinari (1992), and Aspin & Sandell (1994). Pre-outburst K-band data showed some variation between 9.0 and 9.5 mag. Post-outburst, Aspin & Sandell (1994) documented K-band brightness variation between 8.0 and 8.6 mag. Based on the small amplitude of ≈ 1 mag of the brightness increase, the post-outburst brightness fluctuations, and the emission lines in its spectrum, both Eislöffel et al. (1991) and Aspin & Sandell (1994) have concluded that SVS 13 underwent an EXor or similar outburst, but both papers left the possibility open that the outburst may be of a different nature.

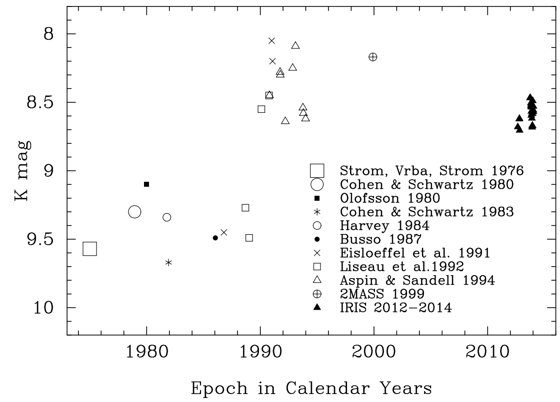


Figure 4: The K-band lightcurve of SVS 13 from its discovery in 1974 to the present, as compiled by Hodapp & Chini (2014). The labels give the bibliographic reference, not the epoch of the observations.

Khanzadyan et al. (2003) have studied the photometric behavior of SVS 13 a decade after the outburst and concluded that the object had not yet returned to its pre-outburst brightness. Another decade later, Hodapp & Chini (2014) re-examined the older infrared photometry, corrected for aperture effects based on infrared images, and obtained new photometric data. Figure 4 shows these aperture-corrected K-band photometric values and clearly demonstrates that SVS 13 has not declined back to its pre-outburst (< 1990) brightness.

Traditionally, optically detected eruptive young variables are classified into either FU Orionis (FUor) or EX Lupi (EXor) type outbursts, depending on the duration of the outburst and its spectrum. FUor outbursts exhibit time scales of decades to centuries and the spectral characteristics of an optically thick luminous disk with absorption lines (e.g., Greene, Aspin, & Reipurth, 2008), while the less substantive EXor outbursts have timescales of years, have been observed to actually return to pre-outburst brightness, and show optically thin emission line spectra, as was documented by Herbig et al. (2001) and Aspin et al. (2010).

The elevated post-outburst level of accretion activity in SVS 13 has persisted for the past two decades to the present, so that the light curve of SVS 13 shares the long duration maximum with FUors, while spectroscopically, it resembles an EXor with CO bandheads in emission (Takami et al., 2006), and the small outburst amplitude resembles neither. This includes SVS 13 in a slowly growing number of younger, more deeply embedded eruptive stars that defy a classification as either FUor or EXor and suggest that a continuous range of outburst characteristics may be a better way to understand this phenomenon.

H_2 Shock Front Proper Motions

Jets emanating from young stars are often comprised of a series of individual shock fronts that have been postulated to arise from changes in the jet velocity as a result of repetitive eruptive events, as described in the review by Reipurth & Bally (2001), and SVS 13 is certainly a prominent example of this phenomenon.

The proper motions of the shock fronts of the HH 7–11 system associated with SVS 13 have been studied at optical wavelengths by Herbig & Jones (1983) and Noriega-Crespo & Garnavich (2001), in the infrared in the H_2 1–0 S(1) line by [Noriega-Crespo et al. (2002) using the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS), by Khanzadyan et al. (2003) using the United Kingdom Infrared Telescope (UKIRT), and with the Spitzer Space Telescope by Raga et al. (2013). These studies all gave proper motions of the shock fronts in the range of 33 mas yr^{-1} that establish a kinematic expansion age of 2100 yrs for the most distant shock front studied there, the HH 7 bow shock.

On the small spatial scales now accessible with adaptive optics, the SVS 13 outflow, at present, originates as a micro-jet of $\approx 0\farcs2$ length, detectable in [FeII] and oriented at P.A. 145°. As seen in Fig. 5 the bright parts of the [FeII] microjet reach up to the boundary of a H_2 S(1) bubble, but fainter [FeII] emission can be traced another $\approx 0\farcs2$ to near the center of the bubble.

Using cross-correlations of the images taken at different times, Hodapp & Chini (2014) determined a kinematic formation time of the smallest bubble near SVS 13 in the year 1980, which gives an upper limit to the true age of the bubble, assuming that it has been expanding at constant velocity. Since, realistically, the bubble is expanding into the dense environment of a molecular core, the true age of this youngest bubble will be younger than the kinematic expansion age and is therefore consistent with this expanding bubble having been generated in the 1990 photometric outburst of SVS 13.

They also obtained an estimate of the kinematic age for the faint third shock front visible near the bottom of the 100 mas image of Fig. 2 for which they derived a kinematic formation time in the year 1919 $\pm$ 7. It was not possible to obtain a reliable kinematic age for the middle shock-excited feature at $\approx 1\farcs5$ from the star, between those two aforementioned features (Fig. 2). The fact that this rather poorly defined system of shock fronts lies pretty precisely in the middle of the 1980 and 1919 (kinematic formation times) features suggests that it must have formed around 1950. If there is a regular pattern to the formation of these bubbles, which with only three examples cannot be convincingly established yet, the next outburst could be expected within the next decade.

It should be noted, as was already pointed out by Khanzadyan et al. (2003), that the proper motion of the major shock fronts in the older parts of the SVS 13 outflow indicate a much longer time interval between shock-front generating events: about 500 yrs. It is not clear whether SVS 13 exhibits multiple periods, or whether the frequency of ejection events has recently increased. An argument for the latter point of view may be that the outflow direction has apparently changed in the past century.

With the exception of this most recent H_2 bubble, the other recent mass ejection events from SVS 13 have ejected material initially in a more southerly direction (P.A. $\approx$ 155° - 159°), as seen in Figs. 2 and 5. The larger scale proper motion study by Raga et al. (2013) based on Spitzer 4.5 μm images shows some emission knots to the SE of SVS 13 with a proper motion vector generally to the SE, in particular the Herbig-Haro knots 7, 8, and 10. North of SVS 13, in the counterflow, they find an emission knot with a generally northern proper motion vector (P.A. -10°). The H_2 S(1) emission outlines a curved, S-shaped path of the SVS 13 outflow. The orientation of the two bubbles at P.A. $\approx$ 159° is roughly point-symmetric to the orientation of outflowing material in the counter–jet found by Bachiller et al. (2000) in CO and Raga et al. (2013) at 4.5 μm.

The more distant parts of the H_2 S(1) emission NW of SVS 13 are anti-parallel, but laterally displaced, from the HH 7-11 system of emission knots. We suggest that the HH 7-11 chain, the system of bubbles immediately south of SVS 13, the emission knots north of SVS 13, and the more distant emission knots further to the NW (Fig. 2) are all part of the same bipolar outflow originating in SVS 13. This outflow has the S-shaped morphology indicative of a precessing or otherwise unstable jet source. Corroborating this, radio interferometry mapping of molecular emission near SVS 13 by Bachiller et al. (2000) has similarly found an orientation of high-velocity material south of SVS 13 different than the HH 7-11 Herbig-Haro chain. They had already concluded that the differences in the alignment of features of different age indicate a precessing source of the outflow.

For the older shock fronts, Davis et al. (2001) determined an inclination of 40° against the line of sight, while Takami et al. (2006) found inclinations in the range of 20° to 40° and Hodapp & Chini (2014) found the youngest bubble to be inclined only 18° against the line of sight. Irrespective

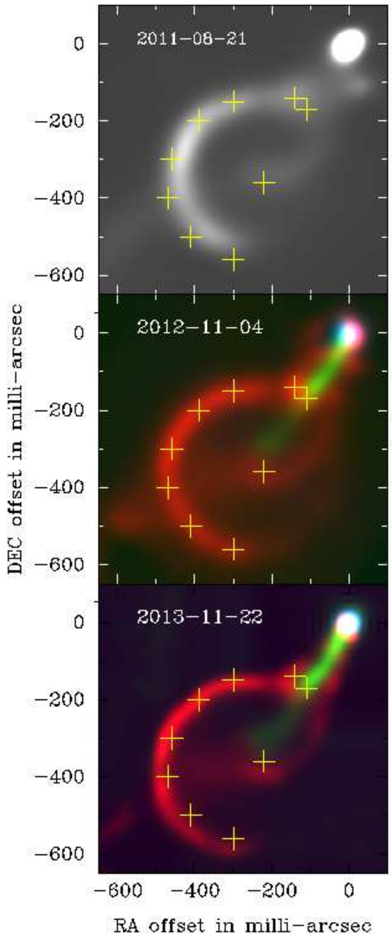


Figure 5: The SVS 13 bubble in 2011, 2012, and 2013. False color images composed of the deconvolved and continuum-subtracted H_2 S(1) image (red) and the continuum subtracted [FeII] emission line (green) aligned on the position of SVS 13 to better than 1 mas. To mark the position of the continuum source SVS 13 without washing out the jet emission, the blue channel shows only 10% of the continuum flux near the [FeII] line. A few fiducial marks indicate positions of the H_2 bubble rim in 2012. The comparison of these marks to the images taken earlier and later clearly indicates the expansion motion of the bubble.

of which of the shock fronts are measured, all data indicate that the outflow emerging from SVS 13 is generally pointed strongly towards the observer. This explains why the counterjet, which moves away from the observer and into the molecular core around SVS 13, is not detectable at optical or near-infrared wavelengths.

The microjet observed in [FeII] shows high radial velocity, but there are no features that would allow a proper motion measurement. At the point where the [FeII] jet, apparently, enters the expanding H_2 bubble, the excitation conditions change and the brightness of the jet drops dramatically. The length of the [FeII] jet is therefore limited by the expanding and moving H_2 bubble surface. This is responsible for the impression, noted already by Davis et al. (2006), that the [FeII] emission looks stationary.

The chain of bubble fragments and their proper motions suggest that bubble-generating events are occurring repetitively, roughly every 30 years, at the present time. The light curve also implies that the next outburst of SVS 13 will likely start from a brighter state of SVS 13 than the previous one. So in addition to the repetitive outbursts, we are also observing cumulative changes in SVS 13.

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Abstracts of recently accepted papers

Discovery of a Disk Gap Candidate at 20 AU in TW Hydrae

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We present a new Subaru/HiCIAO high-contrast H-band polarized intensity (PI) image of a nearby transitional disk associated with TW Hydrae. The scattered light from the disk was detected from 0.″2 to 1.″5 (11–81 AU) and the PI image shows a clear axisymmetric depression in polarized intensity at ∼0.″4 (∼20 AU) from the central star, similar to the ∼80 AU gap previously reported from HST images. Azimuthal polarized intensity profile also shows the disk beyond 0.″2 is almost axisymmetric. We discuss two possible scenarios explaining the origin of the polarized intensity depression: 1) a gap structure may exist at ∼20 AU from the central star because of shallow slope seen in the polarized intensity profile, and 2) grain growth may be occurring in the inner region of the disk. Multi-band observations at NIR and millimeter/sub-millimeter wavelengths play a complementary role in investigating dust opacity and may help reveal the origin of the gap more precisely.

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First Results from High Angular Resolution ALMA Observations Toward the HL Tau Region

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We present Atacama Large Millimeter/submillimeter Array (ALMA) observations from the 2014 Long Baseline Campaign in dust continuum and spectral line emission from the HL Tau region. The continuum images at wavelengths of 2.9, 1.3, and 0.87 mm have unprecedented angular resolutions of 0.″075 (10 AU) to 0.″025 (3.5 AU), revealing an astonishing level of detail in the circumstellar disk surrounding the young solar analogue HL Tau, with a pattern of bright and dark rings observed at all wavelengths. By fitting ellipses to the most distinct rings, we measure precise values for the disk inclination (46.72°±0.05°) and position angle (+138.02°±0.07°). We obtain a high-fidelity image of the 1.0 mm spectral index (α), which ranges from $\alpha \sim 2.0$ in the optically-thick central peak and two brightest rings, increasing to 2.3-3.0 in the dark rings. The dark rings are not devoid of emission, and we estimate a grain emissivity index of 0.8 for the innermost dark ring and lower for subsequent dark rings, consistent with some degree of grain growth and evolution. Additional clues that the rings arise from planet formation include an increase in their central offsets with radius and the presence of numerous orbital resonances. At a resolution of 35 AU, we resolve the molecular component of the disk in HCO^+ (1-0) which exhibits a pattern over LSR velocities from 2-12 km s^{-1} consistent with Keplerian motion around a ∼1.3M$_\odot$ star, although complicated by absorption at low blue-shifted velocities. We also serendipitously detect and resolve the nearby protostars XZ Tau (A/B) and LkHα358 at 2.9 mm.

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Are protoplanetary disks born with vortices? – Rossby wave instability driven by protostellar infall

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We carry out two-fluid, two-dimensional global hydrodynamic simulations to test whether protostellar infall can trigger

Rossby wave instability (RWI) in protoplanetry disks. Our results show that infall can trigger the RWI and generate vortices near the outer edge of the mass landing on the disk (i.e. centrifugal radius). We find that the RWI is triggered under a variety of conditions, although the details depend on the disk parameters and the infall pattern. The common key feature of triggering the RWI is the steep radial gradient of the azimuthal velocity induced by the local increase in density at the outer edge of the infall region. Vortices form when the instability enters the nonlinear regime. In our standard model where self-gravity is neglected, vortices merge together to a single vortex within ~ 20 local orbital times, and the merged vortex survives for the remaining duration of the calculation (> 170 local orbital times). The vortex takes part in outward angular momentum transport, with a Reynolds stress of $\lesssim 10^{-2}$. Our two-fluid calculations show that vortices efficiently trap dust particles with stopping times of the order of the orbital time, locally enhancing the dust to gas ratio for particles of the appropriate size by a factor of ~ 40 in our standard model. When self-gravity is considered, however, vortices tend to be impeded from merging and may eventually dissipate. We conclude it may well have that protoplanetary disks have favorable conditions for vortex formation during the protostellar infall phase, which might enhance early planetary core formation.

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Time evolution of snow regions and planet traps in an evolving protoplanetary disk

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Aims. We track the time evolution of planet traps and snowlines in a viscously evolving protoplanetary disk using an opacity table that accounts for the composition of the dust material.
Methods. We coupled a dynamical and thermodynamical disk model with a temperature-dependent opacity table (that accounts for the sublimation of the main dust components) to investigate the formation and evolution of snowlines and planet traps during the first million years of disk evolution.
Results. Starting from a minimum mass solar nebula (MMSN), we find that the disk mid-plane temperature profile shows several plateaux (0.1–1 AU wide) at the different sublimation temperatures of the species that make up the dust. For water ice, the correspond- ing plateau can be larger than 1 AU, which means that this is a snow "region" rather than a snow "line". As a consequence, the surface density of solids in the snow region may increase gradually, not abruptly. Several planet traps and desert regions appear naturally as a result of abrupt local changes in the temperature and density profiles over the disk lifetime. These structures are mostly located at the edges of the temperature plateaux (surrounding the dust sublimation lines) and at the heat-transition barrier where the disk stellar heating and viscous heating are of the same magnitude (around 10 AU after 1 Myr).
Conclusions. Several traps are identified: although a few appear to be transient, most of them slowly migrate along with the heat- transition barrier or the dust sublimation lines. These planet traps may temporarily favor the growth of planetary cores.

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New evolutionary models for pre-main sequence and main sequence low-mass stars down to the hydrogen-burning limit

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We present new models for low-mass stars down to the hydrogen-burning limit that consistently couple atmosphere and interior structures, thereby superseding the widely used BCAH98 models. The new models include updated molecular linelists and solar abundances, as well as atmospheric convection parameters calibrated on 2D/3D radiative hydrodynamics simulations. Comparison of these models with observations in various colour-magnitude diagrams for

various ages shows significant improvement over previous generations of models. The new models can solve flaws that are present in the previous ones, such as the prediction of optical colours that are too blue compared to M dwarf observations. They can also reproduce the four components of the young quadruple system LkCa 3 in a colour-magnitude diagram with one single isochrone, in contrast to any presently existing model. In this paper we also highlight the need for consistency when comparing models and observations, with the necessity of using evolutionary models and colours based on the same atmospheric structures.

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Combining radiative transfer and diffuse interstellar medium physics to model star formation

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We present a method for modelling star-forming clouds that combines two different models of the thermal evolution of the interstellar medium (ISM). In the combined model, where the densities are low enough that at least some part of the spectrum is optically thin, a model of the thermodynamics of the diffuse ISM is more significant in setting the temperatures. Where the densities are high enough to be optically thick across the spectrum, a model of flux limited diffusion is more appropriate. Previous methods either model the low-density interstellar medium and ignore the thermal behaviour at high densities (e.g. inside collapsing molecular cloud cores), or model the thermal behaviour near protostars but assume a fixed background temperature (e.g. ≈ 10 K) on large-scales. Our new method treats both regimes. It also captures the different thermal evolution of the gas, dust, and radiation separately. We compare our results with those from the literature, and investigate the dependence of the thermal behaviour of the gas on the various model parameters. This new method should allow us to model the ISM across a wide range of densities and, thus, develop a more complete and consistent understanding of the role of thermodynamics in the star formation process.

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Kinematic and Thermal Structure at the onset of high-mass star formation

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Context. Even though high-mass stars are crucial for understanding a diversity of processes within our galaxy and beyond, their formation and initial conditions are still poorly constrained.
Aims. We want to understand the kinematic and thermal properties of young massive gas clumps prior to and at the earliest evolutionary stages of high-mass star formation. Do we find signatures of gravitational collapse? Do we find temperature gradients in the vicinity or absence of infrared emission sources? Do we find coherent velocity structures toward the center of the dense and cold gas clumps?
Methods. To determine kinematics and gas temperatures, we used ammonia, because it is known to be a good tracer and thermometer of dense gas. We observed the NH_3 (1,1) and (2,2) lines within seven very young high-mass star-forming regions comprised of infrared dark clouds (IRDCs), along with ISO-selected far-infrared emission sources

(ISOSS) with the Karl G. Jansky Very Large Array (VLA) and the Effelsberg 100m telescope.
Results. The molecular line data allows us to study velocity structures, linewidths, and gas temperatures at high spatial resolution of 3-5″, corresponding to ~ 0.05 pc at a typical source distance of 2.5 kpc. We find on average cold gas clumps with temperatures in the range between 10 K and 30 K. The observations do not reveal a clear correlation between infrared emission peaks and ammonia temperature peaks. Several infrared emission sources show ammonia temperature peaks up to 30 K, whereas other infrared emission sources show no enhanced kinetic gas temperature in their surrounding. We report an upper limit for the linewidth of $\sim 1.3\ km\,s^{-1}$, at the spectral resolution limit of our VLA observation. This indicates a relatively low level of turbulence on the scale of the observations. Velocity gradients are present in almost all regions with typical velocity differences of 1 to 2 $km\,s^{-1}$ and gradients of 5 to 10 $km\,s^{-1}\,pc^{-1}$. These velocity gradients are smooth in most cases, but there is one exceptional source (ISOSS23053), for which we find several velocity components with a steep velocity gradient toward the clump centers that is larger than 30 $km\,s^{-1}\,pc^{-1}$. This steep velocity gradient is consistent with recent models of cloud collapse. Furthermore, we report a spatial correlation of ammonia and cold dust, but we also find decreasing ammonia emission close to infrared emission sources.

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Near Infrared High Resolution Spectroscopy and Spectro-astrometry of Gas in Disks around Herbig Ae/Be Stars

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In this review, we describe how high resolution near infrared spectroscopy and spectro-astrometry have been used to study the disks around Herbig Ae/Be stars. We show how these tools can be used to identify signposts of planet formation and elucidate the mechanism by which Herbig Ae/Be stars accrete. We also highlight some of the artifacts that can complicate the interpretation of spectro-astrometric measurements and discuss best practices for mitigating these effects. We conclude with a brief discussion of the value of long term monitoring of these systems.

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Power-law tails in probability density functions of molecular cloud column density

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Power-law tails are often seen in probability density functions (PDFs) of molecular cloud column densities, and have been attributed to the effect of gravity. We show that extinction PDFs of a sample of five molecular clouds obtained at a few tenths of a parsec resolution, probing extinctions up to $A_V \sim 10$ magnitudes, are very well described by lognormal functions provided that the field selection is tightly constrained to the cold, molecular zone and that noise and foreground contamination are appropriately accounted for. In general, field selections that incorporate warm, diffuse material in addition to the cold, molecular material will display apparent core+tail PDFs. The apparent tail, however, is best understood as the high extinction part of a lognormal PDF arising from the cold, molecular part of the cloud. We also describe the effects of noise and foreground/background contamination on the PDF structure, and show that these can, if not appropriately accounted for, induce spurious tails or amplify any that are truly present.

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Kiloparsec-Scale Simulations of Star Formation in Disk Galaxies III. Structure and Dynamics of Filaments and Clumps in Giant Molecular Clouds

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We present hydrodynamic simulations of self-gravitating dense gas in a galactic disk, exploring scales ranging from 1 kpc down to ~ 0.1 pc. Our primary goal is to understand how dense filaments form in Giant Molecular Clouds (GMCs). These structures, often observed as Infrared Dark Clouds (IRDCs) in the Galactic plane, are thought to be the precursors to massive stars and star clusters, so their formation may be the rate limiting step controlling global star formation rates in galactic systems as described by the Kennicutt-Schmidt relation. Our study follows on from Van Loo et al. (2013, Paper I), which carried out simulations to 0.5 pc resolution and examined global aspects of the formation of dense gas clumps and the resulting star formation rate. Here, using our higher resolution, we examine the detailed structural, kinematic and dynamical properties of dense filaments and clumps, including mass surface density (Σ) probability distribution functions, filament mass per unit length and its dispersion, lateral Σ profiles, filament fragmentation, filament velocity gradients and infall, and degree of filament and clump virialization. Where possible, these properties are compared to observations of IRDCs. By many metrics, especially too large mass fractions of high $\Sigma > 1$ g cm^{-2} material, too high mass per unit length dispersion due to dense clump formation, too high velocity gradients and too high velocity dispersion for a given mass per unity length, the simulated filaments differ from observed IRDCs. We thus conclude that IRDCs do not form from global fast collapse of GMCs. Rather, we expect IRDC formation and collapse is slowed significantly by the influence of dynamically important magnetic fields, which may thus play a crucial role in regulating galactic star formation rates.

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Gas inside the 97 au cavity around the transition disk Sz 91

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We present ALMA (Cycle 0) band-6 and band-3 observations of the transition disk Sz 91. The disk inclination and position angle are determined to be $i = 49.^\circ5 \pm 3.^\circ5$ and PA $= 18.^\circ2 \pm 3.^\circ5$ and the dusty and gaseous disk are detected up to ~220 AU and ~400 AU from the star, respectively. Most importantly, our continuum observations indicate that the cavity size in the mm-sized dust distribution must be ~97 AU in radius, the largest cavity observed around a T Tauri star. Our data clearly confirms the presence of CO (2–1) well inside the dust cavity. Based on these observational constrains we developed a disk model that simultaneously accounts for the CO and continuum observations (i.e.,

gaseous and dusty disk). According to our model, most of the millimeter emission comes from a ring located between 97 and 140 AU. We also find that the dust cavity is divided into an innermost region largely depleted of dust particles ranging from the dust sublimation radius up to 85 AU, and a second, moderately dust-depleted region, extending from 85 to 97 AU. The extremely large size of the dust cavity, the presence of gas and small dust particles within the cavity and the accretion rate of Sz 91 are consistent with the formation of multiple (giant) planets.

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The Brightening of Re50N: Accretion Event or Dust Clearing?

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The luminous Class I protostar HBC 494, embedded in the Orion A cloud, is associated with a pair of reflection nebulae, Re50 and Re50N, which appeared sometime between 1955 and 1979. We have found that a dramatic brightening of Re50N has taken place sometime between 2006 and 2014. This could result if the embedded source is undergoing a FUor eruption. However, the near-infrared spectrum shows a featureless very red continuum, in contrast to the strong CO bandhead absorption displayed by FUors. Such heavy veiling, and the high luminosity of the protostar, is indicative of strong accretion but seemingly not in the manner of typical FUors. We favor the alternative explanation that the major brightening of Re50N and the simultaneous fading of Re50 is caused by curtains of obscuring material that cast patterns of illumination and shadows across the surface of the molecular cloud. This is likely occurring as an outflow cavity surrounding the embedded protostar breaks through to the surface of the molecular cloud. Several Herbig-Haro objects are found in the region.

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An Optical Survey of the Partially Embedded Young Cluster in NGC 7129

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NGC 7129 is a bright reflection nebula located in the molecular cloud complex near l =105.4, b =+9.9, about 1.15 kpc distant. Embedded within the reflection nebula is a young cluster dominated by a compact grouping of four early-type stars: BD+65°1638 (B3V), BD+65°1637 (B3e), SVS 13 (B5e), and LkHα 234 (B8e). About 80 Hα emission sources brighter than V ∼23 are identified in the region, many of which are presumably T Tauri star members of the cluster. We also present deep (V∼23), optical (VR_CI_C) photometry of a field centered on the reflection nebula and spectral types for more than 130 sources determined from low dispersion, optical spectroscopy. The narrow pre-main sequence evident in the color-magnitude diagram suggests that star formation was rapid and coeval. A median age of about 1.8 Myr is inferred for the Hα and literature-identified X-ray emission sources having established spectral types, using pre-main sequence evolutionary models. Our interpretation of the structure of the molecular cloud and the distribution of young stellar objects is that BD+65°1638 is primarily responsible for evacuating the blister-like cavity within the molecular cloud. LkHα 234 and several embedded sources evident in near infrared adaptive optics imaging have formed recently within the ridge of compressed molecular gas. The compact cluster of low-mass stars formed concurrently with the early-type members, concentrated within a central radius of ∼0.7 pc. Star formation is

simultaneously occurring in a semi-circular arc some ∼3 pc in radius that outlines remaining dense regions of molecular gas. High dispersion, optical spectra are presented for BD+65°1638, BD+65°1637, SVS 13, LkHα 234, and V350 Cep. These spectra are discussed in the context of the circumstellar environments inferred for these stars.

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The Luminosity of Population III Star Clusters

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We analyze the time evolution of the luminosity of a cluster of Population III protostars formed in the early universe. We argue from the Jeans criterion that primordial gas can collapse to form a cluster of first stars that evolve relatively independently of one another (i.e., with negligible gravitational interaction). We model the collapse of individual protostellar clumps using 2+1D nonaxisymmetric numerical hydrodynamics simulations. Each collapse produces a protostar surrounded by a massive disk (i.e., $M_{\rm disk}/M_* > 0.1$), whose evolution we follow for a further 30–40 kyr. Gravitational instabilities result in the fragmentation and the formation of gravitationally bound clumps within the disk. The accretion of these fragments by the host protostar produces accretion and luminosity bursts on the order of $10^6\,{\rm L}_\odot$. Within the cluster, we show that a simultaneity of such events across several protostellar cluster members can elevate the cluster luminosity to 5–10× greater than expected, and that the cluster spends $\sim 15\%$ of its star-forming history at these levels. This enhanced luminosity effect is particularly enabled in clusters of modest size with $\simeq$ 10–20 members. In one such instance, we identify a confluence of burst events that raise the luminosity to nearly 1000× greater than the cluster mean luminosity, resulting in $L > 10^8\,{\rm L}_\odot$. This phenomenon arises solely through the gravitational-instability–driven episodic fragmentation and accretion that characterizes this early stage of protostellar evolution.

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Submillimeter Array High-angular Resolution Observations of the Monoceros R2 Star Forming Cluster

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We present the first high-angular resolution study of the MonR2 star-forming complex carried out with the Submillimeter Array at (sub-)millimeter wavelengths. We image the continuum and molecular line emission toward the young stellar objects in MonR2 at 0.85 mm and 1.3 mm, with resolutions ranging from 0.5” to ∼ 3”. While free-free emission dominates the IRS1 and IRS2 continuum, dust thermal emission prevails for IRS3 and IRS5, giving envelope masses of ∼0.1-0.3 $M_\odot$. IRS5 splits into at least two sub-arcsecond scale sources, IRS5B and the more massive IRS5A. Our ^{12}CO(2-1) images reveal 11 previously unknown molecular outflows in the MonR2 clump. Comparing these outflows with known IR sources in the IRS5 and IRS3 subclusters allows for tentative identification of driving stars. Line images of molecular species such as CH_3CN or CH_3OH show that, besides IRS3 (a well-known hot molecular core), IRS5 is also a chemically active source in the region. The gas excitation temperature derived from CH_3CN lines toward IRS5 is 144 ± 15 K, indicating a deeply embedded protostar at the hot-core evolutionary stage. SED fitting of IRS5 gives a mass of ∼7 $M_\odot$ and a luminosity of 300 $L_\odot$ for the central source. The derived physical properties of the CO outflows suggest that they contribute to the turbulent support of the MonR2 complex and to the gas velocity dispersion in the clump’s center. The detection of a large number of CO outflows widespread across the region supports the competitive accretion scenario as origin of the MonR2 star cluster.

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Chemical evolution in the early phases of massive star formation II: Deuteration

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The chemical evolution in high-mass star-forming regions is still poorly constrained. Studying the evolution of deuterated molecules allows to differentiate between subsequent stages of high-mass star formation regions due to the strong temperature dependence of deuterium isotopic fractionation. We observed a sample of 59 sources including 19 infrared dark clouds, 20 high-mass protostellar objects, 11 hot molecular cores and 9 ultra-compact HII regions in the (3-2) transitions of the four deuterated molecules, DCN, DNC, DCO^+ and N_2D^+ as well as their non-deuterated counterpart.
The overall detection fraction of DCN, DNC and DCO^+ is high and exceeds 50% for most of the stages. N_2D^+ was only detected in a few infrared dark clouds and high-mass protostellar objects. It can be related to problems in the bandpass at the frequency of the transition and to low abundances in the more evolved, warmer stages. We find median D/H ratios of 0.02 for DCN, 0.005 for DNC, 0.0025 for DCO^+ and 0.02 for N_2D^+. While the D/H ratios of DNC, DCO^+ and N_2D^+ decrease with time, DCN/HCN peaks at the hot molecular core stage. We only found weak correlations of the D/H ratios for N_2D^+ with the luminosity of the central source and the FWHM of the line, and no correlation with the H_2 column density. In combination with a previously observed set of 14 other molecules (Paper I) we fitted the calculated column densities with an elaborate 1D physico-chemical model with time-dependent D-chemistry including ortho- and para-H_2 states. Good overall fits to the observed data have been obtained the model. It is one of the first times that observations and modeling have been combined to derive chemically based best-fit models

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Variation of the ultraviolet extinction law across the Taurus-Auriga star forming complex. A GALEX based study

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The Taurus-Auriga molecular complex (TMC) is the main laboratory for the study of low mass star formation. The density and properties of interstellar dust are expected to vary across the TMC. These variations trace important processes such as dust nucleation or the magnetic field coupling with the cloud. In this article, we show how the combination of near ultraviolet (NUV) and infrared (IR) photometry can be used to derive the strength of the 2175 Angstroms bump and thus any enhancement in the abundance of small dust grains and PAHs in the dust grains size distribution. This technique is applied to the envelope of the TMC, mapped by the GALEX All Sky Survey (AIS). UV and IR photometric data have been retrieved from the GALEX-AIS and the 2MASS catalogues.

NUV and K-band star counts have been used to identify the areas in the cloud envelope where the 2175 Angstroms bump is weaker than in the diffuse ISM namely, the low column density extensions of L1495, L1498 and L1524 in Taurus, L1545, L1548, L1519, L1513 in Auriga and L1482-83 in the California region. This finding agrees with previous results on dust evolution derived from Spitzer data and suggests that dust grains begin to decouple from the environmental galactic magnetic field already in the envelope.

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The Impact of Dust Evolution and Photoevaporation on Disk Dispersal

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Protoplanetary disks are dispersed by viscous evolution and photoevaporation in a few million years; in the interim small, sub-micron sized dust grains must grow and form planets. The time-varying abundance of small grains in an evolving disk directly affects gas heating by far-ultraviolet photons, while dust evolution affects photoevaporation by changing the disk opacity and resulting penetration of FUV photons in the disk. Photoevaporative flows, in turn, selectively carry small dust grains leaving the larger particles—which decouple from the gas—behind in the disk. We study these effects by investigating the evolution of a disk subject to viscosity, photoevaporation by EUV, FUV and X-rays, dust evolution, and radial drift using a 1-D multi-fluid approach (gas + different dust grain sizes) to solve for the evolving surface density distributions. The 1-D evolution is augmented by 1+1D models constructed at each epoch to obtain the instantaneous disk structure and determine photoevaporation rates. The implementation of a dust coagulation/fragmentation model results in a marginal decrease in disk lifetimes when compared to models with no dust evolution; the disk lifetime is thus found to be relatively insensitive to the evolving dust opacity. We find that photoevaporation can cause significant reductions in the gas/dust mass ratio in the planet-forming regions of the disk as it evolves, and may result in a corresponding increase in heavy element abundances relative to hydrogen. We discuss implications for theories of planetesimal formation and giant planet formation, including the formation of gas-poor giants. After gas disk dispersal, $\sim 3 \times 10^{-4}$ $M_\odot$ of mass in solids typically remain, comparable to the solids inventory of our solar system.

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Isolating signatures of major cloud-cloud collisions using position-velocity diagrams

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Collisions between giant molecular clouds are a potential mechanism for triggering the formation of massive stars, or even super star clusters. The trouble is identifying this process observationally and distinguishing it from other mechanisms. We produce synthetic position-velocity diagrams from models of: cloud-cloud collisions, non-interacting clouds along the line of sight, clouds with internal radiative feedback and a more complex cloud evolving in a galactic disc, to try and identify unique signatures of collision. We find that a broad bridge feature connecting two intensity peaks, spatially correlated but separated in velocity, is a signature of a high velocity cloud-cloud collision. We show that the broad bridge feature is resilient to the effects of radiative feedback, at least to around 2.5 Myr after the formation of the first massive (ionising) star. However for a head on 10 km s^{-1} collision we find that this will only be observable from 20–30 per cent of viewing angles. Such broad-bridge features have been identified towards M20, a very young region of massive star formation that was concluded to be a site of cloud-cloud collision by Torii et al. (2011), and also towards star formation in the outer Milky Way by Izumi et al. (2014).

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The Gould Belt 'MISFITS' Survey: The Real Solar Neighborhood Protostars

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We present an HCO^+ $J = 3$–2 survey of Class 0+I and Flat SED young stellar objects (YSOs) found in the Gould Belt clouds by surveys with Spitzer. Our goal is to provide a uniform Stage 0+I source indicator for these embedded protostar candidates. We made single point HCO^+ $J = 3$–2 measurements toward the source positions at the CSO and APEX of 546 YSOs (89% of the Class 0+I + Flat SED sample). Using the criteria from van Kempen et al. (2009), we classify sources as Stage 0+I or bona fide protostars and find that 84% of detected sources meet the criteria. We recommend a timescale for the evolution of Stage 0+I (embedded protostars) of 0.54 Myr. We find significant correlations of HCO^+ integrated intensity with α and $T_{\rm bol}$ but not with $L_{\rm bol}$. The detection fraction increases smoothly as a function of α and $L_{\rm bol}$, while decreasing smoothly with $T_{\rm bol}$. Using the Stage 0+I sources tightens the relation between protostars and high extinction regions of the cloud; 89% of Stage I sources lie in regions with $A_V > 8$ mag. Class 0+I and Flat SED YSOs that are not detected in HCO^+ have, on average, a factor of $\sim$2 higher $T_{\rm bol}$ and a factor of $\sim$5 lower $L_{\rm bol}$ than YSOs with HCO^+ detections. We find less YSO contamination, defined as the number of undetected YSOs divided by the total number surveyed, for sources with $T_{\rm bol} \lesssim 600$ K and $L_{\rm bol} \gtrsim 1$ $L_\odot$. The contamination percentage is >90% at $A_V < 4$ mag and decreases as A_V increases.

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High-resolution 25 μm imaging of the disks around Herbig Ae/Be stars

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We imaged circumstellar disks around 22 Herbig Ae/Be stars at 25 μm using Subaru/COMICS and Gemini/T-ReCS. Our sample consists of equal numbers of objects belonging to the two categories defined by Meeus et al. (2001); 11 group I (flaring disk) and II (flat disk) sources. We find that group I sources tend to show more extended emission than group II sources. Previous studies have shown that the continuous disk is hard to be resolved with 8 meter class telescopes in Q-band due to the strong emission from the unresolved innermost region of the disk. It indicates that

the resolved Q-band sources require a hole or gap in the disk material distribution to suppress the contribution from the innermost region of the disk. As many group I sources are resolved at 25 μm, we suggest that many, not all, group I Herbig Ae/Be disks have a hole or gap and are (pre-)transitional disks. On the other hand, the unresolved nature of many group II sources at 25 μm supports that group II disks have continuous flat disk geometry. It has been inferred that group I disks may evolve into group II through settling of dust grains to the mid-plane of the proto-planetary disk. However, considering growing evidence for the presence of a hole or gaps in the disk of group I sources, such an evolutionary scenario is unlikely. The difference between groups I and II may reflect different evolutionary pathways of protoplanetary disks.

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Rethinking a Mysterious Molecular Cloud

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I present high-resolution column density maps of two molecular clouds having strikingly different star formation rates. To better understand the unusual, massive G216−2.5, a molecular cloud with no massive star formation, the distribution of its molecular gas is compared to that of the Rosette Molecular Cloud. Far-infrared data from Herschel are used to derive $N(H_2)$ maps of each cloud and are combined with I_{CO} data to determine the CO-to-H_2 ratio, X_{CO}. In addition, the probability distribution functions (PDFs) and cumulative mass fractions of the clouds are compared. For G216−2.5, $<N(H_2)>= 7.8 \times 10^{20}$ cm^{-2} and $<X_{CO}>= 2.2 \times 10^{20}$ (K km s^{-1})$^{-1}$; for the Rosette, $<N(H_2)>= 1.8 \times 10^{21}$ cm^{-2} and $<X_{CO}>= 2.8 \times 10^{20}$ (K km s^{-1})$^{-1}$. The PDFs of both clouds are log-normal for extinctions below ∼2 mag and both show departures from log-normality at high extinctions. Although it is the less-massive cloud, the Rosette has a higher fraction of its mass in the form of dense gas and contains 1389 $M_\odot$ of gas above the so-called extinction threshold for star formation, $A_V = 7.3$ mag. The G216−2.5 cloud has 874 $M_\odot$ of dense gas above this threshold.

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Using FUV to IR Variability to Probe the Star-Disk Connection in the Transitional Disk of GM Aur

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We analyze 3 epochs of ultraviolet (UV), optical and near-infrared (NIR) observations of the Taurus transitional disk GM Aur using the *Hubble Space Telescope* Imaging Spectrograph (STIS) and the *Infrared Telescope Facility* SpeX spectrograph. Observations were separated by one week and 3 months in order to study variability over multiple timescales. We calculate accretion rates for each epoch of observations using the STIS spectra and find that those separated by one week had similar accretion rates ($\sim 1 \times 10^{-8}$ M$_\odot$ yr^{-1}) while the epoch obtained 3 months later had a substantially lower accretion rate ($\sim 4 \times 10^{-9}$ M$_\odot$ yr^{-1}). We find that the decline in accretion rate is caused by lower densities of material in the accretion flows, as opposed to a lower surface coverage of the accretion columns. During the low accretion rate epoch we also observe lower fluxes at both far UV (FUV) and IR wavelengths, which trace molecular gas and dust in the disk, respectively. We find that this can be explained by a lower dust and gas mass in the inner disk. We attribute the observed variability to inhomogeneities in the inner disk, near the corotation radius, where gas and dust may co-exist near the footprints of the magnetospheric flows. These FUV–NIR data offer

a new perspective on the structure of the inner disk, the stellar magnetosphere, and their interaction.

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Growth of asteroids, planetary embryos and Kuiper belt objects by chondrule accretion

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Chondrules are millimeter-sized spherules that dominate primitive meteorites (chondrites) originating from the asteroid belt. The incorporation of chondrules into asteroidal bodies must be an important step in planet formation, but the mechanism is not understood. We show that the main growth of asteroids can result from gas-drag-assisted accretion of chondrules. The largest planetesimals of a population with a characteristic radius of 100 km undergo run-away accretion of chondrules within ∼3 Myr, forming planetary embryos up to Mars sizes along with smaller asteroids whose size distribution matches that of main belt asteroids. The aerodynamical accretion leads to size-sorting of chondrules consistent with chondrites. Accretion of mm-sized chondrules and ice particles drives the growth of planetesimals beyond the ice line as well, but the growth time increases above the disk life time outside of 25 AU. The contribution of direct planetesimal accretion to the growth of both asteroids and Kuiper belt objects is minor. In contrast, planetesimal accretion and chondrule accretion play more equal roles for the formation of Moon-sized embryos in the terrestrial planet formation region. These embryos are isolated from each other and accrete planetesimals only at a low rate. However, the continued accretion of chondrules destabilizes the oligarchic configuration and leads to the formation of Mars-sized embryos and terrestrial planets by a combination of direct chondrule accretion and giant impacts.

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The Relationship Between the Dust and Gas-Phase CO Across the California Molecular Cloud

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We present results of an extinction– CO line survey of the southeastern part of the California Molecular Cloud (CMC). Deep, wide-field, near-infrared images were used to construct a sensitive, relatively high resolution (~ 0.5 arc min) (NICEST) extinction map of the region. The same region was also surveyed in the ^{12}CO(2-1), ^{13}CO(2-1), C^{18}O(2-1) emission lines at the same angular resolution. These data were used to investigate the relation between the molecular gas, traced by CO emission lines, and the dust column density, traced by extinction, on spatial scales of 0.04 pc across the cloud. We found strong spatial variations in the abundances of ^{13}CO and C^{18}O that were correlated with variations in gas temperature, consistent with temperature dependent CO depletion/desorption on dust grains. The ^{13}CO to C^{18}O abundance ratio was found to increase with decreasing extinction, suggesting selective photodissociation of $C^{18}O$ by the ambient UV radiation field. The effect is particularly pronounced in the vicinity of an embedded cluster where the UV radiation appears to have penetrated deeply (i.e., $A_V \lesssim 15$ mag) into the cloud. We derived the cloud averaged X-factor to be $<X_{CO}> = 2.53 \times 10^{20}$ cm^{-2} (K km s^{-1})$^{-1}$, a value somewhat higher than the Milky Way average. On sub-parsec scales we find there is no single empirical value of the ^{12}CO X-factor that can characterize the molecular gas in cold ($T_k \lesssim 15$ K) cloud regions, with $X_{CO} \propto A_V^{0.74}$ for $A_V \gtrsim 3$ magnitudes. However in regions containing relatively hot ($T_{ex} \gtrsim 25$ K) molecular gas we find a clear correlation between W(^{12}CO) and A_V over a large ($3 \lesssim A_V \lesssim 25$ mag) range of extinction. This results in a constant $X_{CO} = 1.5 \times 10^{20}$ cm^{-2} (K km s^{-1})$^{-1}$ for the hot gas, a lower value than either the average for the CMC or the Milky Way. Overall we find an (inverse) correlation between X_{CO} and T_{ex} in the cloud with $X_{CO} \propto T_{ex}{}^{-0.7}$. This correlation suggests that the global X-factor of a Giant Molecular Cloud (GMC) may depend on the relative amounts of hot gas contained within the cloud.

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Jet Motion, Internal Working Surfaces, and Nested Shells in the Protostellar System HH 212

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HH 212 is a nearby (400 pc) highly collimated protostellar jet powered by a Class 0 source in Orion. We have mapped the inner 80″ (∼0.16 pc) of the jet in SiO (J = 8–7) and CO (J = 3–2) simultaneously at ∼0.5 resolution with the Atacama Millimeter/Submillimeter Array at unprecedented sensitivity. The jet consists of a chain of knots, bow shocks, and sinuous structures in between. As compared to that seen in our previous observations with the Submillimeter Array, it appears to be more continuous, especially in the northern part. Some of the knots are now seen associated with small bow shocks, with their bow wings curving back to the jet axis, as seen in pulsed jet simulations. Two of them are reasonably resolved, showing kinematics consistent with sideways ejection, possibly tracing the internal working surfaces formed by a temporal variation in the jet velocity. In addition, nested shells are seen in CO around the jet axis connecting to the knots and bow shocks, driven by them. The proper motion of the jet is estimated to be ∼115±50 km s^{-1}, comparing to our previous observations. The jet has a small semi-periodical wiggle, with a period of ∼93 yrs. The amplitude of the wiggle first increases with the distance from the central source and then stays roughly constant. One possible origin of the wiggle could be the kink instability in a magnetized jet.

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X-ray emission from stellar jets by collision against high-density molecular clouds: an application to HH 248

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We investigate the plausibility of detecting X-ray emission from a stellar jet that impacts against a dense molecular cloud. This scenario may be usual for classical T Tauri stars with jets in dense star-forming complexes. We first model the impact of a jet against a dense cloud by 2D axisymmetric hydrodynamic simulations, exploring different configurations of the ambient environment. Then, we compare our results with XMM-Newton observations of the Herbig-Haro object HH 248, where extended X-ray emission aligned with the optical knots is detected at the edge of the nearby IC 434 cloud. Our simulations show that a jet can produce plasma with temperatures up to 10 MK, consistent with production of X-ray emission, after impacting a dense cloud. We find that jets denser than the ambient medium but less dense than the cloud produce detectable X-ray emission only at the impact onto the cloud. From the exploration of the model parameter space, we constrain the physical conditions (jet density and velocity, cloud density) that reproduce well the intrinsic luminosity and emission measure of the X-ray source possibly associated with HH 248. Thus, we suggest that the extended X-ray source close to HH 248 corresponds to the jet impacting on a dense cloud.

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Initial Fragmentation in the Infrared Dark Cloud G28.53-0.25

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To study the fragmentation and gravitational collapse of dense cores in infrared dark clouds (IRDCs), we have obtained submillimeter continuum and spectral line data as well as multiple inversion transitions of NH3 and H2O maser data of four massive clumps in an IRDC G28.53-0.25. Combining single dish and interferometer NH3 data, we derive the rotation temperature of G28.53. We identity 12 dense cores at 0.1 pc scale based on submillimeter continuum, and obtain their physical properties using NH3 and continuum data. By comparing the Jeans masses of cores with the core masses, we find that turbulent pressure is important in supporting the gas when 1 pc scale clumps fragment into 0.1 pc scale cores. All cores have a virial parameter smaller than 1 assuming a inverse squared radial density profile, suggesting they are gravitationally bound, and the three most promising star forming cores have a virial parameter smaller than 1 even taking magnetic field into account. We also associate the cores with star formation activities revealed by outflows, masers, or infrared sources. Unlike what previous studies suggested, MM1 turns out to harbor a few star forming cores and is likely a progenitor of high-mass star cluster. MM5 is intermediate while MM7/8 are quiescent in terms of star formation, but they also harbor gravitationally bound dense cores and have the potential of forming stars as in MM1.

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Planetary Collisions outside the Solar System: Time Domain Characterization of Extreme Debris Disks

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Luminous debris disks of warm dust in the terrestrial planet zones around solar-like stars are recently found to vary, indicative of ongoing large-scale collisions of rocky objects. We use Spitzer 3.6 and 4.5 μm time-series observations in 2012 and 2013 (extended to 2014 in one case) to monitor 5 more debris disks with unusually high fractional luminosities ("extreme debris disk"), including P1121 in the open cluster M47 (80 Myr), HD 15407A in the AB Dor moving group (80 Myr), HD 23514 in the Pleiades (120 Myr), HD 145263 in the Upper Sco Association (10 Myr), and the field star BD+20 307 (>1 Gyr). Together with the published results for ID8 in NGC 2547 (35 Myr), this makes the first systematic time-domain investigation of planetary impacts outside the solar system. Significant variations with timescales shorter than a year are detected in five out of the six extreme debris disks we have monitored. However, different systems show diverse sets of characteristics in the time domain, including long-term decay or growth, disk temperature variations, and possible periodicity.

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Outer Rotation Curve of the Galaxy with VERA II: Annual Parallax and Proper Motion of the Star-Forming Region IRAS21379+5106

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We conducted astrometric VLBI observations of water-vapor maser emission in the massive star forming region IRAS 21379+5106 to measure the annual parallax and proper motion, using VERA. The annual parallax was measured to be 0.262±0.031 mas corresponding to a trigonometric distance of $3.82^{+0.51}_{-0.41}$ kpc. The proper motion was $(\mu_\alpha \cos\delta, \mu_\delta)$ = (−2.74±0.08,−2.87±0.18) mas yr^{-1}. Using this result, the Galactic rotational velocity was estimated to be V_θ = 218±19 km s^{-1} at the Galactocentric distance R = 9.22±0.43 kpc, when we adopted the Galactic constants R_0 = 8.05±0.45 kpc and V_0 = 238±14 km s^{-1}. With newly determined distance, the bolometric luminosity of the central young stellar object was re-evaluated to (2.15±0.54) × 10^3 $L_\odot$, which corresponds to spectral type of B2–B3. Maser features were found to be distributed along a straight line from south-west to north-east. In addition, a vector map of the internal motions constructed from the residual proper motions implies that maser features trace a bipolar flow and that it cannot be explained by simple ballistic motion.

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Friends of Hot Jupiters II: No Correspondence Between Hot-Jupiter Spin-Orbit Misalignment and the Incidence of Directly Imaged Stellar Companions

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Multi-star systems are common, yet little is known about a stellar companion's influence on the formation and evolution of planetary systems. For instance, stellar companions may have facilitated the inward migration of hot Jupiters toward to their present day positions. Many observed short-period gas giant planets also have orbits that are misaligned with respect to their star's spin axis, which has also been attributed to the presence of a massive outer companion on a non-coplanar orbit. We present the results of a multi-band direct imaging survey using Keck NIRC2 to measure the fraction of short-period gas giant planets found in multi-star systems. Over three years, we completed a survey of 50 targets ("Friends of Hot Jupiters") with 27 targets showing some signature of multi-body interaction (misaligned or eccentric orbits) and 23 targets in a control sample (well-aligned and circular orbits). We report the masses, projected separations, and confirmed common proper motion for the 19 stellar companions found around 17 stars. Correcting for survey incompleteness, we report companion fractions of $48\% \pm 9\%$, $47\% \pm 12\%$, and $51\% \pm 13\%$ in our total, misaligned/eccentric, and control samples, respectively. This total stellar companion fraction is 2.8σ larger than the fraction of field stars with companions approximately 50-2000 AU. We observe no correlation between misaligned/eccentric hot Jupiter systems and the incidence of stellar companions. Combining this result with our previous radial velocity survey, we determine that $72\% \pm 16\%$ of hot Jupiters are part of multi-planet and/or multi-star systems.

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Dependency of dynamical ejections of O stars on the masses of very young star clusters

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Massive stars can be efficiently ejected from their birth clusters through encounters with other massive stars. We study how the dynamical ejection fraction of O star systems varies with the masses of very young star clusters, $M_{\rm ecl}$, by means of direct N-body calculations. We include diverse initial conditions by varying the half-mass radius, initial mass-segregation, initial binary fraction and orbital parameters of the massive binaries. The results show robustly that the ejection fraction of O star systems exhibits a maximum at a cluster mass of $10^{3.5}\,M_\odot$ for all models, even though the number of the ejected systems increases with cluster mass. We show that lower mass clusters ($M_{\rm ecl} \approx 400\,M_\odot$) are the dominant sources for populating the Galactic field with O stars by dynamical ejections, considering the mass function of embedded clusters. About 15 per cent (up to ≈38 per cent, depending on the cluster models) of O stars of which a significant fraction are binaries, and which would have formed in a ≈10 Myr epoch of star formation in a distribution of embedded clusters, will be dynamically ejected to the field. Individual clusters may eject 100 per cent of their original O star content. A large fraction of such O stars have velocities up to only 10 $\mathrm{km\,s^{-1}}$. Synthesising a young star cluster mass function it follows, given the stellar-dynamical results presented here, that the observed fractions of field and runaway O stars, and the binary fractions among them can be well understood theoretically if all O stars form in embedded clusters.

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The Gould's Belt Very Large Array Survey II: The Serpens region

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We present deep (∼17 μJy) radio continuum observations of the Serpens molecular cloud, the Serpens south cluster, and the W40 region obtained using the Very Large Array in its A configuration. We detect a total of 146 sources, 29 of which are young stellar objects (YSOs), 2 are BV stars and 5 more are associated with phenomena related to YSOs. Based on their radio variability and spectral index, we propose that about 16 of the remaining 110 unclassified sources are also YSOs. For approximately 65% of the known YSOs detected here as radio sources, the emission is most likely non-thermal, and related to stellar coronal activity. As also recently observed in Ophiuchus, our sample of YSOs with X-ray counterparts lies below the fiducial Güdel & Benz relation. Finally, we analyze the proper motions of 9 sources in the W40 region. This allows us to better constrain the membership of the radio sources in the region.

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Chemical composition of the circumstellar disk around AB Aurigae

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Aims. Our goal is to determine the molecular composition of the circumstellar disk around AB Aurigae (hereafter, AB Aur). AB Aur is a prototypical Herbig Ae star and the understanding of its disk chemistry is of paramount importance to understand the chemical evolution of the gas in warm disks.
Methods. We used the IRAM 30-m telescope to perform a sensitive search for molecular lines in AB Aur as part of the IRAM Large program ASAI (A Chemical Survey of Sun-like Star-forming Regions). These data were complemented with interferometric observations of the HCO^+ 1–0 and $C^{17}O$ 1–0 lines using the IRAM Plateau de Bure Interferometer (PdBI). Single-dish and interferometric data were used to constrain chemical models.

Results. Throughout the survey, several lines of CO and its isotopologues, HCO^+, H_2CO, HCN, CN and CS, were detected. In addition, we detected the SO 5_4–3_3 and 5_6–4_5 lines, confirming the previous tentative detection. Comparing to other T Tauri's and Herbig Ae disks, AB Aur presents low HCN 3–2/HCO^+ 3–2 and CN 2–1/HCN 3–2 line intensity ratios, similar to other transition disks. AB Aur is the only protoplanetary disk detected in SO thus far.
Conclusions. We modeled the line profiles using a chemical model and a radiative transfer 3D code. Our model assumes a flared disk in hydrostatic equilibrium. The best agreement with observations was obtained for a disk with a mass of 0.01 $M_\odot$, $R_{\rm in}$ = 110 AU, $R_{\rm out}$ = 550 AU, a surface density radial index of 1.5 and an inclination of 27°. The intensities and line profiles were reproduced within a factor of 2 for most lines. This agreement is reasonable taking into account the simplicity of our model that neglects any structure within the disk. However, the HCN 3–2 and CN 2–1 line intensities were predicted more intense by a factor of >10. We discuss several scenarios to explain this discrepancy.

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The physical state of selected cold clumps

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Context. The study of prestellar cores is essential to understanding the initial stages of star formation. With Herschel more cold clumps have been detected than ever before. For this study we have selected 21 cold clumps from 20 Herschel fields observed as a follow-up on original Planck detections. We have observed these clumps in ^{13}CO (1–0), $C^{18}O$ (1–0), and N_2H^+ (1–0) lines.
Aims. Our aim is to find out if these cold clumps are prestellar. We have examined to what extent independent analysis of the dust and the molecular lines lead to similar conclusions about the masses of these objects.
Methods. We calculate the clump masses and densities from the dust continuum and molecular line observations and compare these to each other and to the virial and Bonnor-Ebert masses calculated for each clump. Finally we examine two of the fields with radiative transfer models to estimate CO abundances.
Results. When excitation temperatures could be estimated, the column densities derived from molecular line observations were comparable to those from dust continuum data. The median column density estimates are 4.2 × 10^{21} cm^{-2} and 5.5 × 10^{21} cm^{-2} for the line and dust emission data, respectively. The calculated abundances, column densities, volume densities, and masses all have large uncertainties and one must be careful when drawing conclusions. Abundance of ^{13}CO was found in modeling the two clumps in the field G131.65+9.75 to be close to the usual value of 10^{-6}. The abundance ratio of ^{13}CO and $C^{18}O$ was ∼10. Molecular abundances could only be estimated with modeling, relying on dust column density data.
Conclusions. The results indicate that most cold clumps, even those with dust color temperatures close to 11 K, are not necessarily prestellar.

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Comparisons between different techniques for measuring mass segregation

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We examine the performance of four different methods which are used to measure mass segregation in star-forming regions: the radial variation of the mass function $\mathcal{M}_{\rm MF}$; the minimum spanning tree-based $\Lambda_{\rm MSR}$ method; the local surface density $\Sigma_{\rm LDR}$ method; and the $\Omega_{\rm GSR}$ technique, which isolates groups of stars and determines whether the

most massive star in each group is more centrally concentrated than the average star. All four methods have been proposed in the literature as techniques for quantifying mass segregation, yet they routinely produce contradictory results as they do not all measure the same thing. We apply each method to synthetic star-forming regions to determine when and why they have shortcomings. When a star-forming region is smooth and centrally concentrated, all four methods correctly identify mass segregation when it is present. However, if the region is spatially substructured, the $\Omega_{\rm GSR}$ method fails because it arbitrarily defines groups in the hierarchical distribution, and usually discards positional information for many of the most massive stars in the region. We also show that the $\Lambda_{\rm MSR}$ and $\Sigma_{\rm LDR}$ methods can sometimes produce apparently contradictory results, because they use different definitions of mass segregation. We conclude that only $\Lambda_{\rm MSR}$ measures mass segregation in the classical sense (without the need for defining the centre of the region), although $\Sigma_{\rm LDR}$ does place limits on the amount of previous dynamical evolution in a star-forming region.

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The Region of Triggered Star Formation W40: Observations and Model

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A "collect and collapse" model of triggered star formation is used to estimate the parameters of ring-like structure consisted of a sequence of low-mass clumps in the W40 region.The model parameters are close to the observed ones if the density of the cloud in which the HII zone is expanding is fairly high ($\gtrsim 10^5$ cm^{-3}) and the luminosity of the driving source exceeds previous estimate. Probable reasons for the scatter of the observed parameters of the clumps are discussed.

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Mid-J CO Shock Tracing Observations of Infrared Dark Clouds I

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Infrared dark clouds (IRDCs) are dense, molecular structures in the interstellar medium that can harbour sites of high-mass star formation. IRDCs contain supersonic turbulence, which is expected to generate shocks that locally heat pockets of gas within the clouds. We present observations of the CO J = 8–7, 9–8, and 10–9 transitions, taken with the Herschel Space Observatory, towards four dense, starless clumps within IRDCs (C1 in G028.37+00.07, F1 and F2 in G034.43+0007, and G2 in G034.77-0.55). We detect the CO J = 8–7 and 9–8 transitions towards three of the clumps (C1, F1, and F2) at intensity levels greater than expected from photodissociation region (PDR) models. The average ratio of the 8–7 to 9–8 lines is also found to be between 1.6 and 2.6 in the three clumps with detections,

significantly smaller than expected from PDR models. These low line ratios and large line intensities strongly suggest that the C1, F1, and F2 clumps contain a hot gas component not accounted for by standard PDR models. Such a hot gas component could be generated by turbulence dissipating in low velocity shocks.

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Scattered Light from Dust in the Cavity of the V4046 Sgr Transition Disk

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We report the presence of scattered light from dust grains located in the giant planet formation region of the circumbinary disk orbiting the $\sim$20-Myr-old close ($\sim$0.045 AU separation) binary system V4046 Sgr AB based on observations with the new Gemini Planet Imager (GPI) instrument. These GPI images probe to within $\sim$7 AU of the central binary with linear spatial resolution of $\sim$3 AU, and are thereby capable of revealing dust disk structure within a region corresponding to the giant planets in our solar system. The GPI imaging reveals a relatively narrow (FWHM $\sim$10 AU) ring of polarized near-infrared flux whose brightness peaks at $\sim$14 AU. This $\sim$14 AU radius ring is surrounded by a fainter outer halo of scattered light extending to $\sim$45 AU, which coincides with previously detected mm-wave thermal dust emission. The presence of small grains that efficiently scatter starlight well inside the mm-wavelength disk cavity supports current models of planet formation that suggest planet-disk interactions can generate pressure traps that impose strong radial variations in the particle size distribution throughout the disk.

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Short- and long-term radio variability of young stars in the Orion Nebula Cluster and Molecular Cloud

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We have used the Karl G. Jansky Very Large Array (VLA) to carry out a multi-epoch radio continuum monitoring of the Orion Nebula Cluster (ONC) and the background Orion Molecular Cloud (OMC) (3 epochs at Q-band and 11 epochs at Ka-band). Our new observations reveal the presence of 19 radio sources, mainly concentrated in the Trapezium Cluster and the Orion Hot Core (OHC) regions. With the exception of the Becklin-Neugebauer (BN) object and the source C (which we identify here as dust emission associated with a proplyd) the sources all show radio variability between the different epochs. We have found tentative evidence of variability in the emission from the massive object related with source I. Our observations also confirm radio flux density variations of a factor >2 on timescales of hours to days in 5 sources. One of these flaring sources, OHC-E, has been detected for the first time.

We conclude that the radio emission can be attributed to two different components: i) highly-variable (flaring) non-thermal radio gyrosynchrotron emission produced by electrons accelerated in the magnetospheres of pre-main sequence low-mass stars; ii) thermal emission due to free-free radiation from ionized gas and/or heated dust around embedded massive objects and proplyds. Combining our sample with other radio monitoring at 8.3 GHz and the X-ray catalog provided by Chandra, we have studied the properties of the entire sample of radio/X-ray stars in the ONC/OMC region (51 sources). We have found several hints of a relation between the X-ray activity and the mechanisms responsible for (at least some fraction of) the radio emission. We have estimated a radio flaring rate of ∼0.14 flares day^{-1} in the dense stellar cluster embedded in the OHC region. This suggests that radio flares are more common events during the first stages of stellar evolution than previously thought. The advent of improved sensitivity with the new VLA and ALMA will dramatically increase the number of stars in young clusters detected at radio wavelengths, which will help us to improve our understanding of the origin and nature of the radio emission.

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Stellar Multiplicity and Debris Disks: An Unbiased Sample

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Circumstellar dust disks have been observed around many nearby stars. However, many stars are part of binary or multiple stellar systems. A natural question arises regarding the presence and properties of such disks in systems with more than one star. To address this, we consider a sample of 449 systems (spectral types A–M) observed with the Herschel Space Observatory as part of the DEBRIS program. We have examined the stellar multiplicity of this sample by gathering information from the literature and performing an adaptive optics imaging survey at Lick Observatory. Five new companions were revealed with our program. In total, we identify 188 (42%) binary or multiple star systems. The multiplicity of the sample is examined with regards to the detection of circumstellar disks for stars of spectral types AFGK.

In general, disks are less commonly detected around binaries than single stars, though the disk frequency is comparable among A stars regardless of multiplicity. However, this sample reveals the period distribution of disk-bearing binaries is consistent with that of non-disk binaries and with comparison field samples. We find that the properties of disks in binary systems are not statistically different from those around single stars. Although the frequency of disk-bearing FGK binaries may be lower than in single star systems, the processes behind disk formation and the characteristics of these disks are comparable among both populations.

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ALMA Observations of the IRDC Clump G34.43+00.24 MM3: DNC/HNC Ratio

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We have observed the clump G34.43+00.24 MM3 associated with an infrared dark cloud in DNC J=3–2, $HN^{13}C$ J=3–2, and N_2H^+ J=3–2 with the Atacama Large Millimeter/submillimeter Array (ALMA). The N_2H^+ emission is found to be relatively weak near the hot core and the outflows, and its distribution is clearly anti-correlated with the CS emission. This result indicates that a young outflow is interacting with cold ambient gas. The $HN^{13}C$ emission is compact and mostly emanates from the hot core, whereas the DNC emission is extended around the hot core. Thus, the DNC and $HN^{13}C$ emission traces warm regions near the protostar differently. The DNC emission is stronger than the $HN^{13}C$ emission toward most parts of this clump. The DNC/HNC abundance ratio averaged within a $15'' \times 15''$ area around the phase center is higher than 0.06. This ratio is much higher than the value obtained by the previous single-dish observations of DNC and $HN^{13}C$ J=1–0 ($\sim$0.003). It seems likely that the DNC and HNC emission observed with the single-dish telescope traces lower density envelopes, while that observed with ALMA traces higher density and highly deuterated regions. We have compared the observational results with chemical-model results in order to investigate the behavior of DNC and HNC in the dense cores. Taking these results into account, we suggest that the low DNC/HNC ratio in the high-mass sources obtained by the single-dish observations are at least partly due to the low filling factor of the high density regions.

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Imaging study of $HCOOCH_3$ toward Orion KL

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We recently reported the first identification of rotational transitions of methyl formate ($HCOOCH_3$) in the second torsionally excited state toward Orion Kleinmann-Low (KL) observed with the Nobeyama 45 m telescope. In combination with the identified transitions of methyl formate in the ground state and the first torsional excited state, it was found that there is a difference in rotational temperature and vibrational temperature, where the latter is higher. In this study, high spatial resolution analysis by using Atacama Large Millimeter/Submillimeter Array (ALMA) science verification data was carried out to verify and understand this difference. Toward the Compact Ridge, two different velocity components at 7.3 and 9.1 km s^{-1} were confirmed, while a single component at 7.3 km s^{-1} was identified towards the Hot Core. The intensity maps in the ground, first, and second torsional excited states have quite similar distributions. Using extensive ALMA data, we determined the rotational and vibrational temperatures for the Compact Ridge and Hot Core by the conventional rotation diagram method. The rotational temperature and vibrational temperatures agree for the Hot Core and for one component of the Compact Ridge. At the 7.3 km s^{-1} velocity component for the Compact Ridge, the rotational temperature was found to be higher than the vibrational temperature. This is different from what we obtained from the results by using the single-dish observation. The difference might be explained by the beam dilution effect of the single-dish data and/or the smaller number of observed transitions within the limited range of energy levels ($\leq$30 K) of E_u in the previous study.

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Star formation in the filament of S254-S258 OB complex: a cluster in the process of making

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Infrared Dark Clouds (IRDCs) are ideal laboratories to study the initial processes of high-mass star and star cluster formation. We investigated star formation activity of an unexplored filamentary dark cloud (size $\sim$ 5.7 pc $\times$ 1.9 pc), which itself is part of a large filament ($\sim$ 20 pc) located in the S254-S258 OB complex at a distance of 2.5 kpc. Using Multi-band Imaging Photometer (MIPS) *Spitzer* 24 μm data, we uncover 49 sources with signal-to-noise ratio greater than 5. We identified 45 sources as candidate young stellar objects (YSOs) of Class I, Flat-spectrum, and Class II nature. Additional 17 candidate YSOs (9 Class I and 8 Class II) are also identified using JHK and Wide-field Infrared Survey Explorer (WISE) photometry. We find that the protostar to Class II sources ratio ($\sim$ 2) and the protostar fraction ($\sim$ 70 %) of the region are high. When the protostar fraction compared to other young clusters, it suggests that the star formation in the dark cloud was possibly started only 1 Myr ago. Combining the near-infrared photometry of the YSO candidates with the theoretical evolutionary models, we infer that most of the candidate YSOs formed in the dark cloud are low-mass ($< 2\ M_\odot$) in nature. We examine the spatial distribution of the YSOs and find that majority of them are linearly aligned along the highest column density line ($N(H_2) \sim 1 \times 10^{22}$ cm^{-2}) of the dark cloud along its long axis at mean nearest neighbor separation of $\sim$ 0.2 pc. Using observed properties of the YSOs, physical conditions of the cloud and a simple cylindrical model, we explore the possible star formation process of this filamentary dark cloud and suggest that gravitational fragmentation within the filament should have played a dominant role in the formation of the YSOs. From the total mass of the YSOs, gaseous mass associated with the dark cloud, and surrounding environment, we infer that the region is presently forming stars at an efficiency $\sim$ 3% and a rate $\sim 30\ M_\odot$ Myr^{-1}, and may emerge to a richer cluster.

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The Environment of the Strongest Galactic Methanol Maser

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The high-mass star-forming site G009.62−00.20 E hosts the 6.7 GHz methanol maser source with the greatest flux density in the Galaxy which has been flaring periodically over the last ten years. We performed high-resolution astrometric measurements of the CH_3OH, H_2O, and OH maser emission and 7 mm continuum in the region. The radio continuum emission was resolved in two sources separated by 1300 AU. The CH_3OH maser cloudlets are distributed along two north-south ridges of emission to the east and west of the strongest radio continuum component. This component likely pinpoints a massive young stellar object which heats up its dusty envelope, providing a constant IR pumping for the Class II CH_3OH maser transitions. We suggest that the periodic maser activity may be accounted for by an independent, pulsating, IR radiation field provided by a bloated protostar in the vicinity of the brightest masers. We also report about the discovery of an elliptical distribution of CH_3OH maser emission in the region of periodic variability.

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Understanding star formation in molecular clouds II. Signatures of gravitational collapse of IRDCs

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We analyse column density and temperature maps derived from Herschel dust continuum observations of a sample of prominent, massive infrared dark clouds (IRDCs) i.e. G11.11-0.12, G18.82-0.28, G28.37+0.07, and G28.53-0.25. We disentangle the velocity structure of the clouds using ^{13}CO 1-0 and ^{12}CO 3-2 data, showing that these IRDCs are the densest regions in massive giant molecular clouds (GMCs) and not isolated features. The probability distribution function (PDF) of column densities for all clouds have a power-law distribution over all (high) column densities, regardless of the evolutionary stage of the cloud: G11.11-0.12, G18.82-0.28, and G28.37+0.07 contain (proto)-stars, while G28.53-0.25 shows no signs of star formation. This is in contrast to the purely log-normal PDFs reported for near and/or mid-IR extinction maps. We only find a log-normal distribution for lower column densities, if we perform PDFs of the column density maps of the whole GMC in which the IRDCs are embedded. By comparing the PDF slope and the radial column density profile of three of our clouds, we attribute the power law to the effect of large-scale gravitational collapse and to local free-fall collapse of pre- and protostellar cores for the highest column densities. A significant impact on the cloud properties from radiative feedback is unlikely because the clouds are mostly devoid of star formation. Independent from the PDF analysis, we find infall signatures in the spectral profiles of ^{12}CO for G28.37+0.07 and G11.11-0.12, supporting the scenario of gravitational collapse. Our results are in line with earlier interpretations that see massive IRDCs as the densest regions within GMCs, which may be the progenitors of massive stars or clusters. At least some of the IRDCs are probably the same features as ridges (high column density regions with $N>10^{23}$ cm^{-2} over small areas), which were defined for nearby IR-bright GMCs. Because IRDCs are only confined to the densest (gravity dominated) cloud regions, the PDF constructed from this kind of a clipped image does not represent the (turbulence dominated) low column density regime of the cloud.

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An Ammonia Spectral Map of the L1495-B218 Filaments in the Taurus Molecular Cloud: I. Physical Properties of Filaments and Dense cores

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We present deep NH_3 observations of the L1495-B218 filaments in the Taurus molecular cloud covering over a 3° angular range using the K-band focal plane array on the 100m Green Bank Telescope. The L1495-B218 filaments form an interconnected, nearby, large complex extending over 8 pc. We observed NH_3 (1,1) and (2,2) with a spectral resolution of 0.038 km s^{-1} and a spatial resolution of 31″. Most of the ammonia peaks coincide with intensity peaks in dust continuum maps at 350 μm and 500 μm. We deduced physical properties by fitting a model to the observed spectra. We find gas kinetic temperatures of 8–15 K, velocity dispersions of 0.05–0.25 km s^{-1}, and NH_3 column densities of $5 \times 10^{12} - 1 \times 10^{14}$ cm^{-2}. The CSAR algorithm, which is a hybrid of seeded-watershed and binary dendrogram algorithms, identifies a total of 55 NH_3 structures including 39 leaves and 16 branches. The masses of the NH_3 sources range from 0.05 $M_\odot$ to 9.5 $M_\odot$. The masses of NH_3 leaves are mostly smaller than their corresponding virial mass estimated from their internal and gravitational energies, which suggests these leaves are gravitationally unbound structures. 9 out of 39 NH_3 leaves are gravitationally bound and 7 out of 9 gravitationally bound NH_3 leaves are associated with star formation. We also found that 12 out of 30 gravitationally unbound leaves are pressure-confined. Our data suggest that a dense core may form as a pressure-confined structure, evolve to a gravitationally bound core, and undergo collapse to form a protostar.

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The properties of discs around planets and brown dwarfs as evidence for disc fragmentation

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Direct imaging searches have revealed many very low-mass objects, including a small number of planetary mass objects, as wide-orbit companions to young stars. The formation mechanism of these objects remains uncertain. In this paper we present the predictions of the disc fragmentation model regarding the properties of the discs around such low-mass objects. We find that the discs around objects that have formed by fragmentation in discs hosted by Sun-like stars (referred to as *parent* discs and *parent* stars) are more massive than expected from the $M_{\rm disc} - M_*$ relation (which is derived for stars with masses $M_* > 0.2$ M$_\odot$). Accordingly, the accretion rates onto these objects are also higher than expected from the $\dot{M}_* - M_*$ relation. Moreover there is no significant correlation between the mass of the brown dwarf or planet with the mass of its disc nor with the accretion rate from the disc onto it. The discs around objects that form by disc fragmentation have larger than expected masses as they accrete gas from the disc of their parent star during the first few kyr after they form. The amount of gas that they accrete and therefore their mass depend on how they move in their parent disc and how they interact with it. Observations of disc masses and accretion rates onto very low-mass objects are consistent with the predictions of the disc fragmentation model. Future observations (e.g. by ALMA) of disc masses and accretion rates onto substellar objects that have even lower masses (young planets and young, low-mass brown dwarfs), where the scaling relations predicted by the disc fragmentation model diverge significantly from the corresponding relations established for higher-mass stars, will test the predictions of this model.

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A Sub-arcsecond Survey Toward Class 0 Protostars in Perseus: Searching for Signatures of Protostellar Disks

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We present a CARMA 1.3 mm continuum survey toward 9 Class 0 protostars in the Perseus molecular cloud at $\sim0\farcs3$ (70 AU) resolution. This study approximately doubles the number of Class 0 protostars observed with spatial resolutions < 100 AU at millimeter wavelengths, enabling the presence of protostellar disks and proto-binary systems to be probed. We detect flattened structures with radii > 100 AU around 2 sources (L1448 IRS2 and Per-emb-14) and these sources may be strong disk candidates. Marginally-resolved structures with position angles within 30° of perpendicular to the outflow are found toward 3 protostars (L1448 IRS3C, IRAS 03282+3035, and L1448C) and are considered disk candidates. Two others (L1448 IRS3B and IRAS 03292+3039) have resolved structure, possibly indicative of massive inner envelopes or disks; L1448 IRS3B also has a companion separated by $0\farcs9$ ($\sim$210 AU). IC348-MMS does not have well-resolved structure and the candidate first hydrostatic core L1451-MMS is marginally resolved on $1''$ scales. The strong disk candidate sources were followed-up with $C^{18}O$ (J=2–1) observations, detecting velocity gradients consistent with rotation, but it is unclear if the rotation is Keplerian. We compare the observed visibility amplitudes to radiative transfer models, finding that visibility amplitude ratios suggest a compact component (possibly a disk) is necessary for 5 of 9 Class 0 sources; envelopes alone may explain the other 4 systems. We conclude that there is evidence for the formation of large disks in the Class 0 phase with a range of radii and masses dependent upon their initial formation conditions.

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Cloud-cloud collision as a trigger of the high-mass star formation; a molecular line study in RCW120

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RCW120 is a Galactic HII region having a beautiful ring shape bright in infrared. Our new CO J=1–0 and J=3–2 observations performed with the NANTEN2, Mopra, and ASTE telescopes have revealed that two molecular clouds with a velocity separation of 20 km s^{-1} are both physically associated with RCW120. The cloud at -8 km s^{-1} apparently traces the infrared ring, while the other cloud at -28 km s^{-1} is distributed just outside the opening of the infrared ring, interacting with the HII region as supported by high kinetic temperature of the molecular gas and by the complementary distribution with the ionized gas. A spherically expanding shell driven by the HII region is usually discussed as the origin of the observed ring structure in RCW120. Our observations, however, indicate no evidence of the expanding motion in the velocity space, being inconsistent with the expanding shell model. We here postulate an alternative that, by applying the model introduced by Habe & Ohta (1992), the exciting O star in RCW120 was formed by a collision between the present two clouds at a colliding velocity $\sim$30 km s^{-1}. In the model, the observed infrared ring can be interpreted as the cavity created in the larger cloud by the collision, whose inner surface is illuminated by the strong UV radiation after the birth of the O star. We discuss that the present cloud-cloud collision scenario explains the observed signatures of RCW120, i.e., its ring morphology, coexistence of the two clouds and their large velocity separation, and absence of the expanding motion.

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Chemical tracers of episodic accretion in low-mass protostars

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Aims: Accretion rates in low-mass protostars can be highly variable in time. Each accretion burst is accompanied by a temporary increase in luminosity, heating up the circumstellar envelope and altering the chemical composition of the gas and dust. This paper aims to study such chemical effects and discusses the feasibility of using molecular spectroscopy as a tracer of episodic accretion rates and timescales. *Methods:* We simulate a strong accretion burst in a diverse sample of 25 spherical envelope models by increasing the luminosity to 100 times the observed value. Using a comprehensive gas-grain network, we follow the chemical evolution during the burst and for up to 10^5 yr after the system returns to quiescence. The resulting abundance profiles are fed into a line radiative transfer code to simulate rotational spectra of $C^{18}O$, HCO^+, $H^{13}CO^+$, and N_2H^+ at a series of time steps. We compare these spectra to observations taken from the literature and to previously unpublished data of HCO^+ and N_2H^+ 6–5 from the Herschel Space Observatory. *Results:* The bursts are strong enough to evaporate CO throughout the envelope, which in turn enhances the abundance of HCO^+ and reduces that of N_2H^+. After the burst, it takes 10^3–10^4 yr for CO to refreeze and for HCO^+ and N_2H^+ to return to normal. The H_2O snowline expands outwards by a factor of $\sim$10 during the burst; afterwards, it contracts again on a timescale of 100–1000 yr. The chemical effects of the burst remain visible in the rotational spectra for as long as 10^5 yr after the burst has ended, highlighting the importance of considering luminosity variations when analyzing molecular line observations in protostars. The spherical models are currently not accurate enough to derive robust timescales from single-dish observations. As follow-up work, we suggest that the models be calibrated against spatially resolved observations in order to identify the best tracers to be used for statistically significant source samples.

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Variable protostellar accretion with episodic bursts

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We present the latest development of the disk gravitational instability and fragmentation model, originally introduced by us to explain episodic accretion bursts in the early stages of star formation. Using our numerical hydrodynamics model with improved disk thermal balance and star-disk interaction, we computed the evolution of protostellar disks formed from the gravitational collapse of prestellar cores. In agreement with our previous studies, we find that cores of higher initial mass and angular momentum produce disks that are more favourable to gravitational instability and fragmentation, while a higher background irradiation and magnetic fields moderate the disk tendency to fragment. The protostellar accretion in our models is time-variable, thanks to the nonlinear interaction between different spiral modes in the gravitationally unstable disk, and can undergo episodic bursts when fragments migrate onto the star owing to the gravitational interaction with other fragments or spiral arms. Most bursts occur in the partly embedded Class I phase, with a smaller fraction taking place in the deeply embedded Class 0 phase and a few possible bursts in the optically visible Class II phase. The average burst duration and mean luminosity are found to be in good agreement with those inferred from observations of FU-Orionis-type eruptions. The model predicts the existence of two types of bursts: the isolated ones, showing well-defined luminosity peaks separated with prolonged periods ($\sim 10^4$ yr) of quiescent accretion, and clustered ones, demonstrating several bursts occurring one after another during just a few hundred years. Finally, we estimate that 40%–70% of the star-forming cores can display bursts after forming a star-disk system.

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arxiv.org/pdf/1503.07888

Close encounters involving free-floating planets in star clusters

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Instabilities in planetary systems can result in the ejection of planets from their host system, resulting in free-floating planets (FFPs). If this occurs in a star cluster, the FFP may remain bound to the star cluster for some time and interact with the other cluster members until it is ejected. Here, we use N-body simulations to characterise close star-planet and planet-planet encounters and the dynamical fate of the FFP population in star clusters containing 500–2000 single or binary star members. We find that FFPs ejected from their planetary system at low velocities typically leave the star cluster 40% earlier than their host stars, and experience tens of close (<1000 AU) encounters with other stars and planets before they escape. The fraction of FFPs that experiences a close encounter depends on both the stellar density and the initial velocity distribution of the FFPs. Approximately half of the close encounters occur within the first 30 Myr, and only 10% occur after 100 Myr. The periastron velocity distribution for all encounters is well-described by a modified Maxwell-Bolzmann distribution, and the periastron distance distribution is linear over almost the entire range of distances considered, and flattens off for very close encounters due to strong gravitational focusing. Close encounters with FFPs can perturb existing planetary systems and their debris structures, and they can result in re-capture of FFPs. In addition, these FFP populations may be observed in young star clusters in imaging surveys; a comparison between observations and dynamical predictions may provide clues to the early phases of stellar and planetary dynamics in star clusters.

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http://arxiv.org/pdf/1503.03077

Dimming and CO absorption toward the AA Tau protoplanetary disk: An infalling flow caused by disk instability?

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AA Tau, a classical T Tauri star in the Taurus cloud, has been the subject of intensive photometric monitoring for more than two decades due to its quasi-cyclic variation in optical brightness. Beginning in 2011, AA Tau showed another peculiar variation – its median optical though near-IR flux dimmed significantly, a drop consistent with a 4-mag increase in visual extinction. It has stayed in the faint state since.Here we present 4.7μm CO rovibrational spectra of AA Tau over eight epochs, covering an eleven-year time span, that reveal enhanced ^{12}CO and ^{13}CO absorption features in the $J_{\rm low} \leq 13$ transitions after the dimming. These newly appeared absorptions require molecular gas along the line of sight with $T \sim 500$ K and a column density of $\log(N_{^{12}\rm CO}) \sim 18.5$ cm^{-2}, with line centers that show a constant 6 km s^{-1} redshift. The properties of the molecular gas confirm an origin in the circumstellar material. We suggest that the dimming and absorption are caused by gas and dust lifted to large heights by a magnetic buoyancy instability. This material is now propagating inward, and on reaching the star within a few years will be observed as an accretion outburst.

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http://arxiv.org/pdf/1503.06359

Fragmentation of Molecular Clumps and Formation of Protocluster

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Sufficiently massive clumps of molecular gas collapse under self-gravity and fragment to spawn a cluster of stars that have a range of masses. We investigate observationally the early stages of formation of a stellar cluster in a massive filamentary infrared dark cloud, G28.34+0.06 P1, in the 1.3mm continuum and spectral line emission using the ALMA. Sensitive continuum data reveal further fragmentation in five dusty cores at a resolution of several 10^3 AU. Spectral line emission from $C^{18}O$, CH_3OH, ^{13}CS, H_2CO and N_2D^+ are detected for the first time toward these dense cores. We found that three cores are chemically more evolved as compared with the other two; interestingly though, all of them are associated with collimated outflows as suggested by evidence from the CO, SiO, CH_3OH, H_2CO and SO emissions. The parsec-scale kinematics in NH_3 exhibit velocity gradients along the filament, consistent with accretion flows toward the clumps and cores. The moderate luminosity and the chemical signatures indicate that the five cores harbor low- to intermediate-mass protostars that likely become massive ones at the end of the accretion. Despite the fact that the mass limit reached by the 1σ dust continuum sensitivity is 30 times lower than the thermal Jeans mass, there is a lack of a distributed low-mass protostellar population in the clump. Our observations indicate that in a protocluster, low-mass stars form at a later stage after the birth of more massive protostars.

Accepted by ApJ

http://arxiv.org/pdf/1503.03017

New Jobs

Postdoc Positions in Star Formation at DIAS

The Dublin Institute for Advanced Studies (DIAS) is offering 2 postgraduate scholarships to work in the Star Formation Group led by Prof. Tom Ray and in collaboration with Dr. Deirdre Coffey of University College Dublin. Funding is available for 4 years starting in September 2015 and includes a stipend, postgraduate fees and provision for conference/workshop participation. The student will work on the interpretation of observations of young stellar objects (YSOs), their disks and outflows.

A primary degree in physics, astronomy or a related field is required. Programming skills and experience with astronomical data analysis are beneficial.

Interested students are encouraged to send a brief statement of research interests, a curriculum vitae, and to arrange for 2 letters of recommendation to be sent directly to Ms. Eileen Flood, (eflood@cp.dias.ie) from whom further information can be obtained. Detailed inquiries can be made to Prof. Tom Ray (tr@cp.dias.ie). The deadline for applications, including receipt of letters of recommendation, is April 30th 2015.

Joint ALMA Observatory Postdoctoral Position

ALMA started its first Early Science observations in late 2011 and has already produced 200 papers, many in influential journals. At the Cycle 2 Call for Proposals, ALMA received more submissions than any other telescope in history. We are offering Postdoctoral Fellowships to join ALMA at this exciting period during which the array is ramping up to its full operational potential. ALMA Postdoctoral Fellows will be appointed for three years and will spend at least half of their time dedicated to their personal research. These Fellowships offer young scientists opportunities and facilities to enhance their research programs through involvement in science activities and close contact with experienced staff at the world's foremost observatory for sub-mm astronomy. Deadline 1 June.

https://cw.na1.hgncloud.com/nrao/loadJobPostingDetails.do?jobPostingID=101040&source=jobList

PhD position in Astrochemistry at the MPIfR

The Millimeter and Submillimeter Astronomy Department of the Max Planck Institute for Radio Astronomy (Bonn, Germany) is offering a PhD position in the field of observational astrochemistry.

The PhD project will focus on the analysis and interpretation of a spectral line survey conducted with the Atacama Large Millimeter/submilllimeter Array (ALMA) toward Sagittarius B2. The aim of the survey is to provide a detailed inventory of the molecular composition of a star forming region and gain insight into the processes that lead to chemical complexity in the interstellar medium. It has already delivered the first interstellar detection of a branched alkyl molecule, which establishes a further link between interstellar chemistry and the molecular composition of meteorites and comets. The aim of the PhD project is to derive the abundance and location of the detected molecules in order to test predictions of state-of-the-art chemical models and set constraints on the evolutionary stage of the sources detected in the field of view.

The successful applicant should have a background in astrophysics, a strong interest in observational astronomy and astrochemistry, some programming experience, and he/she should be proficient in English. The successful candidate will be supported by the SFB 956 Doctoral Program and will be part of the Collaborative Research Center 956 (www.sfb956.de), funded by the German Science Foundation. Candidates must have a university diploma/MSc. in physics, astronomy or a related field. The appointment will be for three years. The salary is based on the E13 TV-L scale (50% - 75% FTE), which accounts for experience and qualification. Health and retirement benefits are included. The Max-Planck Institute for Radioastronomy is an equal opportunity employer in accordance with German laws. Women, minorities, and persons with disabilities are strongly encouraged to apply.

This offer is good until the position is filled. Applications submitted before June 1, 2015 will receive full consideration. Applicants should send a single PDF file containing a curriculum vitae, educational record, and a short statement of research interests. They should also indicate their possible starting date and arrange for two letters of recommendation to be sent to Dr. Arnaud Belloche and Prof. Karl Menten before the deadline. Electronic applications are encouraged.

Contact for further enquiries and electronic applications:

Dr. Arnaud Belloche, belloche@mpifr-bonn.mpg.de

Prof. Dr. Karl Menten, kmenten@mpifr-bonn.mpg.de

Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

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

Applications are invited for one or two postdoctoral fellowships at York University in Toronto. The successful candidate(s) will work with Professor Ray Jayawardhana and his collaborators on observational and analytical studies of extra-solar planets, brown dwarfs and young stars, and will be encouraged to pursue independent research on related topics. On-going and recent projects include photometric and spectroscopic studies of extra-solar planets, high-contrast imaging searches for sub-stellar companions around young stars, investigations of brown dwarf variability and multiplicity, and the SONYC (Substellar Objects in Nearby Young Clusters) ultra-deep survey, using data from VLT, Subaru, Gemini, Keck, CFHT, Kepler, and other major observatories. The position is for two years, with extension to a third year possible, and comes with a competitive salary and funds for research expenses. Start date is negotiable, but summer or fall 2015 is preferred. Applicants should send their curriculum vitae, a description of research interests and plans and a list of publications, and should arrange for three letters of recommendation to be sent directly to marlene@yorku.ca. All materials should be submitted electronically. Applications are accepted until the position is filled, and those received before 2015 May 1 will receive full consideration. Early expressions of interest and inquiries are welcome, and should be made to rayjay@yorku.ca

Summary of Upcoming Meetings

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Moving ... ??

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