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The Star Formation Newsletter

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Cover Picture

The massive young cluster Westerlund 2 in Carina is about 1 - 2 million years old and located at a distance of about 6 kpc. The surrounding molecular clouds contain a number of globules and pillars that all point towards the cluster as they are sculpted by powerful UV radiation and stellar winds from at least a dozen early O-stars. Image obtained with ACS on the HST. The red colors in the nebulosity represent Hα.

Image courtesy NASA, ESA, the Hubble Heritage Team (STScI/AURA), A. Nota (ESA/STScI), and the Westerlund 2 Science Team

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My Favorite Object

A review of the W51 cloud

Adam Ginsburg

1 Overview

The W51 giant molecular cloud is among the most massive and active star-forming regions in our Galaxy. While it was originally discovered as a bright radio source and identified as an H II region Westerhout (1958), Mehringer (1994), it has since become notable as an extremely gas- and dust-rich cloud (Carpenter & Sanders 1998, Ginsburg et al. 2012, Urquhart et al. 2014, Wang et al. 2015). It is particularly notable for its two most luminous high-mass protostars, W51e2 and W51 North, both of which exhibit extreme chemical richness and are sites of uncommon masers (Zhang & Ho 1997, Eisner et al. 2002, Shi et al. 2010a, Henkel et al. 2013, Goddi et al. 2015). This review will discuss W51 in both a Galactic context and in its role as a laboratory for high-mass star formation studies.

2 W51 in the context of the Galaxy

Our Galaxy contains only a few molecular clouds with $M \gtrsim 10^6\ M_\odot$, and these clouds dominate the molecular mass in the Galaxy Combes (1991). Of this sample, W51 is perhaps the most observationally isolated, located in a region of the galaxy with little foreground or background material around $\ell = 49.5, b = -0.4$. Its location has made it an appealing target for large-scale surveys in CO (Carpenter & Sanders 1998, Kang et al. 2010, Parsons et al. 2012), H_2CO (Ginsburg et al. 2015a, Ginsburg et al. 2016b), and HI (Koo 1997).

Millimeter continuum surveys helped reinvigorate interest in this cloud. While in CO, the W51 cloud looks like many other regions in the Galactic plane, in dust the main star formation site, W51A, stands out as particularly luminous, comparable only to W49A and Sgr B2 (Ginsburg et al. 2012, Csengeri et al. 2014). The W51 IRS2 and e1/e2 regions are among a small handful (< 10) of regions that are capable of forming a $M > 10^4\ M_\odot$ cluster in our Galaxy (Ginsburg et al. 2012, Bressert et al. 2012, Urquhart et al. 2014).

2.1 Geography

The W51 cloud appears peculiar in the overall Galactic position-velocity diagram (Dame et al. 2001). Most of the cloud exists at 'forbidden' velocities above the tangent velocity, $v > v_{tan}$. Such a high line-of-sight velocity means the cloud complex is most likely within a few hundred parsecs of the tangent point, but it also implies that either a cloud-cloud collision or a gravitational interaction with a deep potential, e.g., a spiral arm, has accelerated the cloud complex (Ginsburg et al. 2015a). The parallax distance to masers associated with W51A, the main star-forming component of W51, have been measured, giving $D = 5.41^{+0.31}_{-0.28}$ kpc to W51 e2 and e8 (Sato et al. 2010) and $D = 5.1^{+2.9}_{-1.4}$ kpc to W51 IRS2 (Xu et al. 2009). These distances put W51 in the Carina-Sagittarius arm (Reid et al. 2009, Reid et al. 2014).

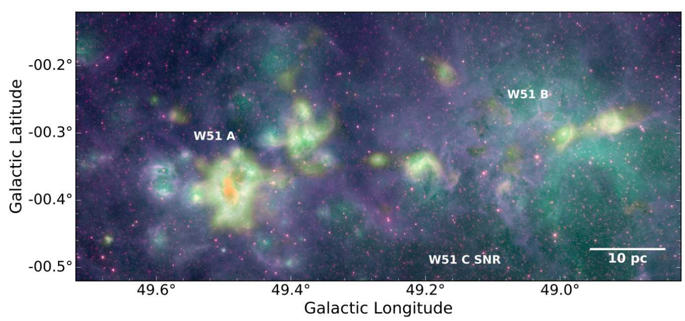

Figure 1: A color composite of W51 with major regions, W51 A, B, and C, labeled. W51 A contains the protoclusters W51 Main and W51 IRS 2; these are blended in the light orange region around 49.5-0.38. The blue, green, and red colors are WISE bands 1, 3, and 4 (3.4, 12, and 22 μm) respectively. The yellow-orange semitransparent layer is from the Bolocam 1.1 mm Galactic Plane Survey data (Aguirre et al. 2011, Ginsburg et al. 2013). This figure was reproduced from (Ginsburg et al. 2015a)

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The W51 cloud complex lies at a latitude $b \sim -0.3$, which given our vantage point 25 pc above the Galactic plane means that W51 is very close to the Galactic midplane. The W51B cloud's elongated dust filament (Koo 1999, Wang et al. 2015) is parallel to the Galactic equator, making the W51B filament a potentially more evolved analog of well-known filamentary "spines" like Nessie (Goodman et al. 2014).

Despite its distance, but perhaps in part because of our vantage point, there is very little molecular gas along the line of sight to W51. Because of the bright, compact H II regions in the cloud, the limits on any such features are fairly strict, $N(H_2) < 10^{21}$ cm^{-2} (Indriolo et al. 2012). Most of the molecular line emission, and absorption, is local to W51, i.e., it is $\sim 5.5 \pm 1$ kpc in that general direction.

There is evidence that the higher velocity clouds, the $\sim 55 - 65$ km s^{-1} W51 A / W51 Main cloud and the 68 km s^{-1} cloud, are closer to each other than their velocities imply, and they are interacting (Carpenter & Sanders 1998, Bieging et al. 2010, Ginsburg et al. 2015a). The lower-velocity clouds around ~ 40 km s^{-1} are behind the other clouds, though it is unclear whether they are part of the W51 complex. Their latitude and on-the-sky proximity to the rest of W51 hints that they are related.

Along the molecular ridge that defines W51A and W51B, there are hints of interaction with the supernova remnant W51C. Direct evidence of this interaction is observed within W51B through high-velocity CO and HI and from shocked SiO emission Koo & Moon 1997b, Koo & Moon 1997c, Aleksic et al. 2012, Brogan et al. 2013, Dumas et al. 2014) and OH masers (Brogan et al. 2013). The extended W51 cloud is at least in part being disrupted by this supernova remnant, as evidenced by a lack of CO emission toward much of the area filled by the radio remnant (Carpenter & Sanders 1998, Bieging et al. 2010, Parsons et al. 2012).

The total infrared luminosity of the W51 protocluster complex has been estimated using IRAS and KAO, $L_{bol} \sim 9.3 \times 10^6 (D/5.4\mathrm{kpc})^2 L_\odot$ (Harvey et al. 1986, Sievers et al. 1991), though Herschel data suggest the total IR luminosity might be a few times larger (Wang et al. 2015, Ginsburg et al. 2016a).

2.2 H II regions

The W51 complex is best known as a collection of bright cm-wavelength radio sources, which all trace H II regions. Mehringer (1994) identified ~ 20 independent H II regions with the VLA. Because these regions are so bright, it has been possible to measure radio recombination line emission at high significance, which allowed measurements of their electron temperature $T_e \approx 7500$ K (Mehringer 1994, Ginsburg et al. 2015a).

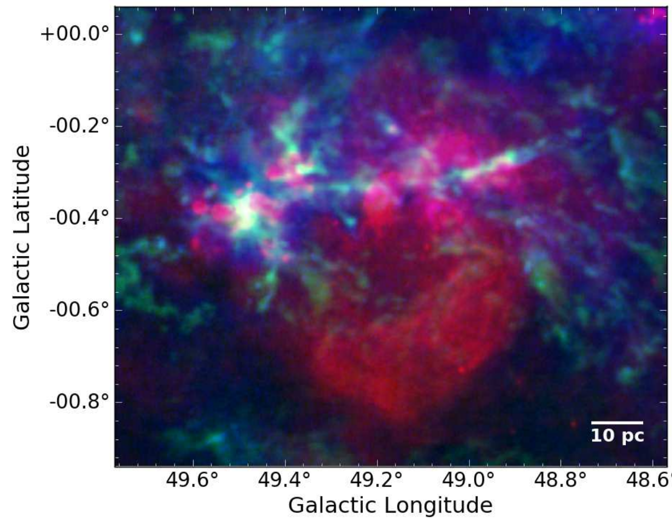

Figure 2: Another RGB figure of the W51 region on an even larger scale. The red layer shows the 90 cm continuum (Brogan et al. 2013), highlighting the W51 C supernova remnant as the extended haze that dominates the image. Blue shows ATLASGAL 870 μm continuum. Green shows the integrated ^{13}CO emission from 30 to 90 km s^{-1} from the Galactic Ring Survey (Jackson et al. 2006).

2.3 High mass star formation within W51A

The W51A complex is the most actively studied part of the cloud complex, as it contains some of the densest and most chemically complex gas in the Galaxy. Because of their high millimeter brightness, the W51 IRS2 and W51 e1/e2 regions have been the target of many millimeter studies revealing CH_3CN (Remijan et al. 2004a, Remijan et al. 2004b), CH_3OCHO (Demyk et al. 2008), H_2Cl+ (Neufeld et al. 2015), HF (Sonnentrucker et al. 2010), [NII] (Persson et al. 2014), and many other species.

Early radio studies of the region revealed the extremely bright and compact source W51e2 and the similarly bright but more diffuse W51 IRS2 region (Mehringer 1994). Early follow-up of these regions showed signs of infalling gas and ongoing accretion onto the H II regions (Zhang & Ho 1997, Young et al. 1998, Keto & Klaassen 2008), though later higher-resolution observations revealed that the infall is likely onto molecular cores adjacent to the H II regions (Shi et al. 2010a,2010b, Goddi et al. 2015,2016).

The W51A complex is rich in molecular masers. All three of the high-mass protostars, W51e2, W51e8, and W51 North contain the usual OH (Etoka et al. 2012), H_2O (Genzel et al. 1981, Imai et al. 2002, Eisner et al. 2002), and CH_3OH masers (Phillips & van Langevelde 2005, Etoka et al. 2012). However, W51 North also contains some rare or unique masers: SiO (Morita et al. 1992, Eisner et al.

2002) and NH_3 (Brown & Cragg 1991, Gaume et al. 1993, Henkel et al. 2013). Both of these classes of masers are only detected toward a few star forming regions in the Galaxy, with 5-8 known in SiO (Morita et al. 1992, Zapata et al. 2009, Ginsburg et al. 2015b, Cordiner et al. 2016), and only 5 in NH_3 (Madden et al. 1986, Walsh et al. 2007). Recent high-resolution ALMA data add to the mystery of these masers, revealing that the NH_3 and SiO masers come from different sources within W51 North separated by only 0.7″ (4000 AU; Goddi et al. 2015, Goddi et al., in prep).

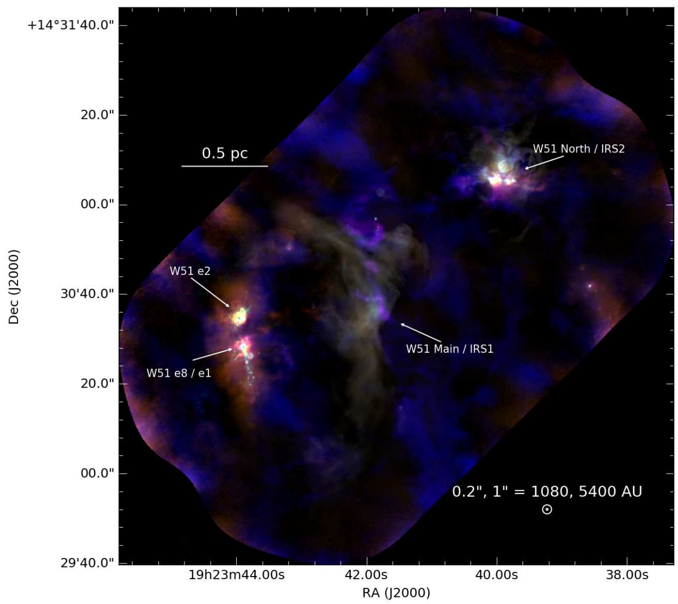

Figure 3: An overview of the W51A region as seen by ALMA and the VLA. The most prominent features are labeled. W51 e8 is a mm dust source, while W51 e1 is the neighboring H II region. Similarly, W51 IRS2 is the H II region, and W51 North is the brightest mm source in that area. The colors are a composite of millimeter emission lines: CO in blue, CH_3OH in orange, and HC_3N in purple (Ginsburg et al. 2017). The 1.3mm continuum is shown in green. The white hazy emission shows VLA Ku-band free-free continuum emission (Ginsburg et al. 2016).

2.4 The stellar population of W51A

The W51A region has a luminosity corresponding to a 5000-10000 $M_\odot$ cluster. Near-infrared observations have identified a small subset of this population. Early infrared studies found about 20 OB stars in the gas-rich, radio-bright region (Okumura et al. 2000, Kumar et al. 2004). These early observations were limited by confusion with the H II regions, especially in W51 Main and W51 IRS2. Those limitations were partly overcome with adaptive optics imaging, which provided the first glimpse into the dense cluster formed within W51 IRS2 and revealed very luminous and young O3/O4 stars and at least one currently accreting O-star (Figueredo et al. 2008, Barbosa et al. 2008).

Despite significant progress in identifying the stellar populations within W51, the most deeply embedded - but nonetheless main-sequence - stellar groups may not yet be identified (Ginsburg et al. 2016a). X-ray observations reveal a genuine cluster associated with W51 IRS2 (Townsley et al. 2014), indicating the presence of many stars that were not detected in the infrared. Radio observations show pointlike sources spread around the most luminous H II region (Mehringer 1994, Ginsburg et al. 2016a), W51 Main, but in this region infrared point sources have been difficult to detect and there is no clear X-ray cluster; it appears that this H II region may be illuminated by a broader OB association that has so far gone mostly uncharacterized (Ginsburg et al. 2016a).

2.5 The stellar population elsewhere

A few independent studies of the stellar population throughout W51 have been performed in the near-infrared (Goldader & Wynn-Williams 1994, Okumura et al. 2000, Kumar et al. 2004). There are some hints of a slightly top-heavy initial mass function in the W51 IRS2 region (Okumura et al. 2000). Kang et al. 2009) studied the embedded stellar population with Spitzer, finding that most of the more massive protostars are associated with or very nearby H II regions. Besides the W51 IRS2 cluster (G49.5-0.4), Kumar et al. (2004) found an additional three embedded clusters in the lower-longitude W51 B region with ages 1-3 Myr and masses 2-10×10^3 $M_\odot$. The existence of these older clusters supports the hypothesis that star formation has been continuously ongoing for ∼ 10 Myr, and led those authors to suggest that star formation in W51 was triggered by interaction with a spiral arm, a notion that is supported by gas kinematics studies (Ginsburg et al. 2015a).

2.6 Peculiar and notable objects within W51: W51 Main

2.6.1 W51 e2

The most famous source in W51, in large part due to its interesting astrochemistry, is W51e2. The source was originally noted as a hypercompact H II region (Mehringer 1994), as it is the brightest compact source in the area. Recent studies have revealed that it breaks into at least two sources, e2w being the HCH II region and e2e a nearby hot molecular core (Shi et al. 2010a,b, Goddi et al. 2016, Ginsburg et al. 2017). The hot core is one of the major targets for discovery of complex chemical species, coming in just behind Orion BN/KL and Sgr B2, likely because of this unique interaction between a very bright radio centimeter continuum backlight and a hot molecular core.

The HCH II region e2w is an appealing target for studies of compact ionized gas since it is so bright. Keto & Klaassen (2008) and Klaassen et al. (2009) observed possible rotation in the ionized gas, suggesting the presence of a disk. More recent observations (Goddi et al. 2016, Ginsburg et al. 2016a) have called this interpretation into question, but it nonetheless represents an important target for this type of study.

2.6.2 W51 e8

There is a cluster of compact H II regions adjacent to W51e2 (Mehringer 1994). The brightest is the extended W51e1 ultracompact H II region, but the most molecularly rich is the W51 e8 hot core. Unique among the hot molecular cores in W51, e8 has a radio continuum detection and therefore contains at least some free-free or synchrotron emission. The W51 e sources lay along a common molecular ridge and are very likely to be within < 1 pc of each other (Ginsburg et al. 2017).

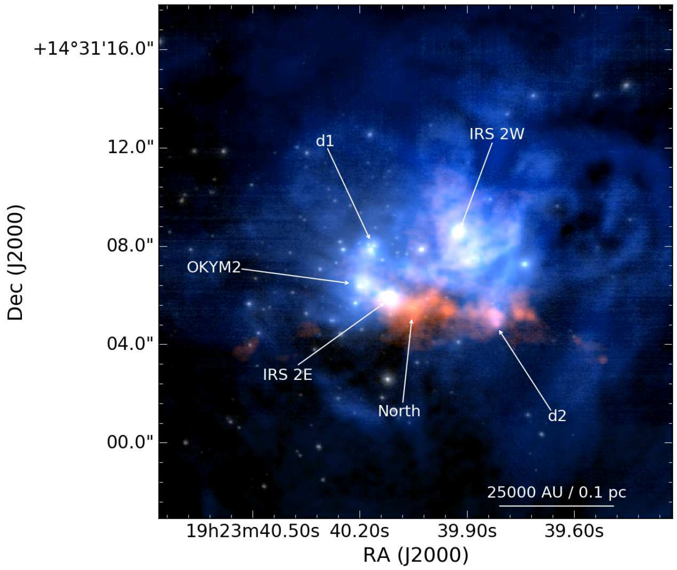

Figure 4: An image of the W51 IRS2 region, consisting of 2 cm VLA Ku-band continuum (blue; Ginsburg et al. 2016a), 1.3 mm ALMA Band 6 continuum (orange; Ginsburg et al. 2017), and near-infrared VLT NAOS CONICA K-band adaptive optics (white; Figueredo et al. 2008) data. The millimeter emission traces a dust ridge containing W51 North (§2.7.1) and d2 (§2.7.2).

2.7 Peculiar and notable objects within W51: W51 IRS 2

W51 IRS2 is the northern of the two major protoclusters in W51. It is powered by at least one O3/O4 star (Barbosa et al. 2008) and contains a luminous compact H II region (Figure 4).

2.7.1 W51 North

The W51 North hot core is directly adjacent to the W51 IRS2 H II region and is at least partly embedded within it. This core contains one of the rare SiO masers, so far detected toward only a handful ($\lesssim 8$) high-mass star-forming regions (Eisner et al. 2002, Zapata et al. 2009, Ginsburg et al. 2015b). It is one of only a small number ($\lesssim 4$ Walsh et al. 2007, Hoffman & Kim 2011a,b) of known metastable and non-metastable NH_3 maser sources (Madden et al. 1986, Mauersberger et al. 1987, Wilson & Henkel 1988, Wilson et al. 1990, Gaume et al. 1993, Henkel et al. 2013, Goddi et al. 2015). It was recently detected at 25 μm, implying that it contains warm dust (Barbosa et al. 2016).

2.7.2 W51d2

W51d2 is the brightest hypercompact H II region in the IRS2 area. It is the only HCH II region that is clearly associated with surrounding molecular gas (Zhang & Ho 1997, Ginsburg et al. 2017). This source also contains one of the rare non-metastable NH_3 masers (see citations for W51 North). It is detected at 25 μm, but not at shorter wavelengths (Barbosa et al. 2016).

2.7.3 W51 IRS2E

IRS2E is a high-mass protostar with a detected circumstellar disk (Barbosa et al. 2008, Figueredo et al. 2008). X-ray emission, notably in the 6.5 keV iron fluorescence line, has been detected toward this source and is variable (Townsley 2005,2014).

2.7.4 The Lacy Jet

There is a bipolar, highly symmetric outflow with Z-symmetry in the IRS2 area. This outflow is unique in that it was first detected entirely in ionized gas emission (Lacy et al. 2007), with the molecular counterpart detected only with ALMA observations a few years later (Ginsburg et al.

2017). Despite its symmetry, which clearly pinpoints an origin position, no obvious centimeter or millimeter line or continuum source has been detected at the base of the outflow; there is a source very near the base, but offset by at least a few hundred AU.

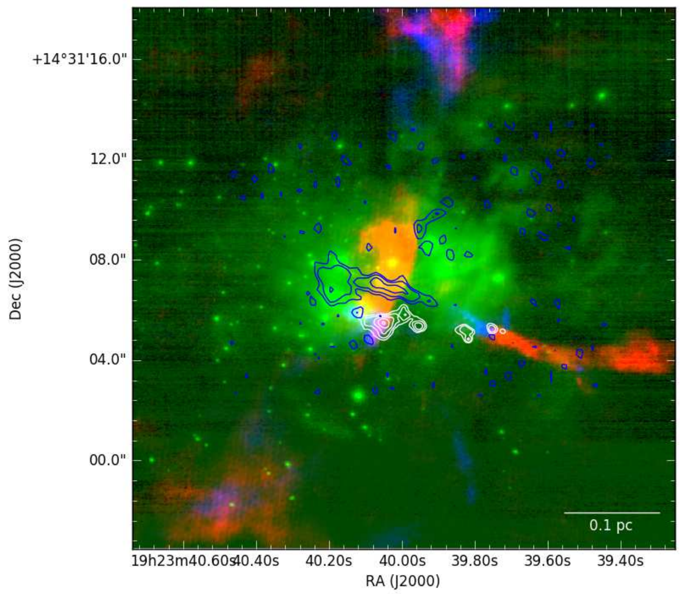

Figure 5: The W51 IRS2 region with a near-infrared K-band background in green (Figueredo et al. 2008), CO outflows in red and blue, ALMA 1.4 mm in white contours (Ginsburg et al. 2017), and high-velocity H77α in blue contours (Ginsburg et al. 2016a). The image shows two clear outflows, the north-south large-scale flow from W51 North and the much more clearly bipolar Lacy jet (§2.7.4) that has no clear origin but exhibits an S-shape symmetry when the ionized gas is included. The symmetry is matched in velocity.

2.8 Peculiar and notable objects within W51: Others

2.8.1 OMN2000 LS1

There is a P Cygni supergiant (an evolved high-mass star that may be a Luminous Blue Variable, though no eruptive outbursts have been detected) in the W51 complex, whose presence indicates that high-mass star formation has been ongoing for > 10 Myr in the cloud (Clark et al. 2009). The lack of other evolved massive stars of a similar age suggests that star formation has been accelerating.

2.8.2 The W51 C Supernova Remnant

W51 C is an extended region of radio emission to the west of W51 A and mostly south of W51 B (Figure 2). It is a source of X-rays (Koo et al. 1995,2002,2005, Hanabata et al. 2013), gamma rays (Abdo et al. 2009), and high-energy cosmic rays (Fang & Zhang 2010). It is interacting with the W51 B cloud (Koo & Moon 1997a,b, Brogan et al. 2013, Ginsburg et al. 2015a). It has evacuated much of the volume of the W51B region of molecular gas and heated much of the remaining gas (Parsons et al. 2012, Ginsburg et al. 2015a). The interaction region between the supernova remnant is visible in very high velocity emission of molecular and atomic tracers (HI and CO) and exhibits OH maser emission (Brogan et al. 2013).

3 Data on W51

W51 has some additional appeal as a laboratory because there is plenty of data available on it. It is included in most Galactic plane surveys (UKIDSS, BGPS, ATLASGAL, HiGAL, Spitzer GLIMPSE/MIPSGAL, GLOSTAR, CORNISH, THOR, BU-GRS) and has many additional data sets that can be found online. Much of the data shown in this review is available on the Dataverse at https://dataverse.harvard.edu/dataverse/W51_ALMA.

4 Conclusion

W51 is an excellent laboratory for the study of high-mass star formation and high-mass cluster formation because of its unique location in the Galaxy. The complex is in one of the least crowded parts of the Galactic plane and it is the closest that contains protoclusters with $M \geq 10^4\ M_\odot$.

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Abstracts of recently accepted papers

On the dynamical evolution of the Orion Trapezium

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We discuss recent observational data on the transverse and radial velocities, as well as on the masses of the main components of the Orion Trapezium. Based on the most reliable values of these quantities we study the dynamical evolution of ensembles of multiple systems mimicking the Orion Trapezium. To this end we conduct numerical N–body integrations using the observed masses, planar positions and velocities, radial velocities, and random line-of-sight (z) positions for all components. We include perturbations in these quantities compatible with the observational errors. We find the dynamical lifetimes of such systems to be quite short, of the order of 10 to 50 thousand years. The end result of the simulations is usually a tight binary, or sometimes a hierarchical triple. The properties of the evolved systems are studied at different values of the crossing times. The frequency distributions of the major semiaxes and eccentricities of the resulting binaries are discussed and compared with observations.

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The ALMA View of the OMC1 Explosion in Orion

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Most massive stars form in dense clusters where gravitational interactions with others stars may be common. The two nearest forming massive stars, the BN object and Source I, located behind the Orion Nebula, were ejected with velocities of ∼29 and ∼13 km s^{-1} about 500 years ago by such interactions. This event generated an explosion in the gas. New ALMA observations show in unprecedented detail, a roughly spherically symmetric distribution of over a hundred ^{12}CO J=2−1 streamers with velocities extending from V_{LSR}=−150 to +145 km s^{-1}. The streamer radial velocities increase (or decrease) linearly with projected distance from the explosion center, forming a 'Hubble Flow' confined to within 50 arcsec of the explosion center. They point toward the high proper-motion, shock-excited H_2 and [Fe II] 'fingertips' and lower-velocity CO in the H_2 wakes comprising Orion's 'fingers'. In some directions, the H_2 'fingers' extend more than a factor of two farther from the ejection center than the CO streamers. Such deviations from spherical symmetry may be caused by ejecta running into dense gas or the dynamics of the N-body interaction that ejected the stars and produced the explosion. This $\sim 10^{48}$ erg event may have been powered by the release of gravitational potential energy associated with the formation of a compact binary or a protostellar merger. Orion may be the prototype for a new class of stellar explosion responsible for luminous infrared transients in nearby galaxies.

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Formation of Massive Rocky Exomoons by Giant Impact

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The formation of satellites is thought to be a natural by-product of planet formation in our Solar System, and thus, moons of extrasolar planets (exomoons) may be abundant in extrasolar planetary systems, as well. Exomoons have yet to be discovered. However, moons larger than 0.1 Earth masses can be detected and characterized using current transit techniques. Here, we show that collisions between rocky planets with masses between a quarter to ten Earth masses can create impact-generated debris disks that could accrete into moons. Collisions between like-sized objects, at oblique impact angles, and velocities near escape speed create disks massive enough to form satellites that are dynamically stable against planetary tides. Impacts of this type onto a superearth between 2 to 7 Earth masses can launch into orbit enough mass to create a satellite large enough to be detected in Kepler transit data. Impact velocity is a crucial controlling factor on disk mass, which has been overlooked in all prior studies of moon formation via planetary collision.

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Rotational spectroscopy, tentative interstellar detection, and chemical modelling of N-methylformamide

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Context. N-methylformamide, CH_3NHCHO, may be an important molecule for interstellar pre-biotic chemistry because it contains a peptide bond, which in terrestrial chemistry is responsible for linking amino acids in proteins. The rotational spectrum of the most stable *trans* conformer of N-methylformamide is complicated by strong torsion-rotation interaction due to the low barrier of the methyl torsion. For this reason, the theoretical description of the rotational spectrum of the *trans* conformer has up to now not been accurate enough to provide a firm basis for its interstellar detection.
Aims. In this context, as a prerequisite for a successful interstellar detection, our goal is to improve the characterization of the rotational spectrum of N-methylformamide.
Methods. We use two absorption spectrometers in Kharkiv and Lille to measure the rotational spectra over the frequency range 45–630 GHz. The analysis is carried out using the Rho-axis method and the RAM36 code. We search for N-methylformamide toward the hot molecular core Sagittarius (Sgr) B2(N2) using a spectral line survey carried out with the Atacama Large Millimeter/submillimeter Array (ALMA). The astronomical spectra are analyzed under the assumption of local thermodynamic equilibrium. The astronomical results are put into a broader astrochemical context with the help of a gas-grain chemical kinetics model.
Results. The new laboratory data set for the *trans* conformer of N-methylformamide consists of 9469 distinct line frequencies with $J \leq 62$, including the first assignment of the rotational spectra of the first and second excited torsional states. All these lines are fitted within experimental accuracy for the first time. Based on the reliable frequency predictions obtained in this study, we report the tentative detection of N-methylformamide towards Sgr B2(N2). We find

N-methylformamide to be more than one order of magnitude less abundant than formamide (NH_2CHO), a factor of two less abundant than the unsaturated molecule methyl isocyanate (CH_3NCO), but only slightly less abundant than acetamide (CH_3CONH_2). We also report the tentative detection of the ^{15}N isotopologue of formamide ($^{15}NH_2CHO$) toward Sgr B2(N2). The chemical models indicate that the efficient formation of HNCO via NH + CO on grains is a necessary step in the achievement of the observed gas-phase abundance of CH_3NCO. Production of CH_3NHCHO may plausibly occur on grains either through the direct addition of functional-group radicals or through the hydrogenation of CH_3NCO.
Conclusions Provided the detection of N-methylformamide is confirmed, the only slight underabundance of this molecule compared to its more stable structural isomer acetamide and the sensitivity of the model abundances to the chemical kinetics parameters suggest that the formation of these two molecules is controlled by kinetics rather than thermal equilibrium.

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A Search for L/T Transition Dwarfs With Pan-STARRS1 and WISE. III. Young L Dwarf Discoveries and Proper Motion Catalogs in Taurus and Scorpius-Centaurus

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We present the discovery of eight young M7–L2 dwarfs in the Taurus star-forming region and the Scorpius-Centaurus OB Association, serendipitously found during a wide-field search for L/T transition dwarfs using Pan-STARRS1 (optical) and *WISE* (mid-infrared) photometry. We identify PSO J060.3200+25.9644 (near-infrared spectral type L1) and PSO J077.1033+24.3809 (L2) as new members of Taurus based on their VL-G gravity classifications, the consistency of their photometry and proper motions with previously known Taurus objects, and the low probability of contamination by field objects. PSO J077.1033+24.3809 is the coolest substellar member of Taurus found to date. Both Taurus objects are among the lowest mass free-floating objects ever discovered, with estimated masses $\approx 6\ M_{\rm Jup}$, and provide further evidence that isolated planetary-mass objects can form as part of normal star-formation processes. PSO J060.3200+25.9644 (a.k.a. DANCe J040116.80+255752.2) was previously identified as a likely member of the Pleiades (age $\approx$ 125 Myr) based on photometry and astrometry, but its VL-G gravity classification and near-infrared photometry imply a much younger age and thus point to Taurus membership. We have also discovered six M7–L1 dwarfs in outlying regions of Scorpius-Centaurus with photometry, proper motions, and low-gravity spectral signatures consistent with membership. These objects have estimated masses $\approx$15–36 $M_{\rm Jup}$. The M7 dwarf, PSO J237.1470−23.1489, shows excess mid-infrared flux implying the presence of a circumstellar disk. Finally, we present catalogs of Pan-STARRS1 proper motions for low-mass members of Taurus and Upper Scorpius with median precisions of $\approx$3 mas yr^{-1}, including 67 objects with no previous proper motion and 359 measurements that improve on literature values.

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Decrease of the organic deuteration during the evolution of Sun-like protostars: the case of SVS13-A

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We present the results of formaldehyde and methanol deuteration measurements towards the Class I low-mass protostar SVS13-A, in the framework of the IRAM 30-m ASAI (Astrochemical Surveys At IRAM) project. We detected emission lines of formaldehyde, methanol, and their deuterated forms (HDCO, D_2CO, CHD_2OH, CH_3OD) with $E_{\rm up}$ up to 276 K. The formaldehyde analysis indicates $T_{\rm kin} \sim 15-30$ K, $n_{\rm H_2} \geq 10^6$ cm^{-3}, and a size of about 1200 AU suggesting an origin in the protostellar envelope. For methanol we find two components: (i) a high temperature ($T_{\rm kin} \sim 80$ K) and very dense ($> 10^8$ cm^{-3}) gas from a hot corino (radius $\simeq$ 35 AU), and (ii) a colder ($T_{\rm kin} \leq 70$ K) and more extended (radius $\simeq$ 350 AU) region.
The deuterium fractionation is 9×10^{-2} for HDCO, 4×10^{-3} for D_2CO, and $2-7 \times 10^{-3}$ for CH_2DOH, up to two orders of magnitude lower than the values measured in Class 0 sources. We derive also formaldehyde deuteration in the outflow: 4×10^{-3}, in agreement with what found in the L1157–B1 protostellar shock. Finally, we estimate $[CH_2DOH]/[CH_3OD] \simeq 2$. The decrease of deuteration in the Class I source SVS13-A with respect to Class 0 sources can be explained by gas-phase processes. Alternatively, a lower deuteration could be the effect of a gradual collapse of less deuterated external shells of the protostellar evelope. The present measurements fill in the gap between prestellar cores and protoplanetary disks in the context of organics deuteration measurements.

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CO_2 infrared emission as a diagnostic of planet-forming regions of disks

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The infrared ro-vibrational emission lines from organic molecules in the inner regions of protoplanetary disks are unique probes of the physical and chemical structure of planet forming regions and the processes that shape them. These observed lines are mostly interpreted with local thermal equilibrium (LTE) slab models at a single temperature. The non-LTE excitation effects of carbon dioxide (CO_2) are studied in a full disk model to evaluate: (i) what the emitting regions of the different CO_2 ro-vibrational bands are; (ii) how the CO_2 abundance can be best traced using CO_2 ro-vibrational lines using future JWST data and; (iii) what the excitation and abundances tell us about the inner disk physics and chemistry. CO_2 is a major ice component and its abundance can potentially test models with migrating icy pebbles across the iceline. A full non-LTE CO_2 excitation model has been built starting from experimental and theoretical molecular data. The characteristics of the model are tested using non-LTE slab models. Subsequently the CO_2 line formation has been modelled using a two-dimensional disk model representative of T-Tauri disks where CO_2 is detected in the mid-infrared by the *Spitzer Space Telescope*. The CO_2 gas that emits in the 15 μm and 4.5 μm regions of the spectrum is not in LTE and arises in the upper layers of disks, pumped by infrared radiation. The v_2 15 μm feature is dominated by optically thick emission for most of the models that fit the observations and increases linearly with source luminosity. Its narrowness compared with that of other molecules stems from a combination of the low rotational excitation temperature ($\sim$ 250 K) and the inherently narrower feature for CO_2. The inferred CO_2 abundances derived for observed disks range from 3×10^{-9} to 1×10^{-7} with respect to total gas density for typical gas/dust ratios of 1000, similar to earlier LTE disk estimates. Line-to-continuum ratios are low, of order a few %, stressing the need for high signal-to-noise ($S/N > 300$) observations for individual line detections. The inferred CO_2 abundances are much lower than those found in interstellar ices ($\sim 10^{-5}$), indicating a reset of the chemistry by high temperature reactions in the inner disk. JWST-MIRI with its higher spectral resolving power will allow a much more accurate retrieval of abundances from individual $P-$ and $R-$branch lines, together with the $^{13}CO_2$ Q-branch at 15 μm. The $^{13}CO_2$ Q-branch is particularly sensitive to possible enhancements of $^{13}CO_2$ due to sublimation of migrating icy pebbles at the iceline(s). Prospects for *JWST*-NIRSpec are discussed as well.

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The Effect of Protoplanetary Disk Cooling Times on the Formation of Gas Giant Planets by Gravitational Instability

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Observational evidence exists for the formation of gas giant planets on wide orbits around young stars by disk gravitational instability, but the roles of disk instability and core accretion for forming gas giants on shorter period orbits are less clear. The controversy extends to population synthesis models of exoplanet demographics and to hydrodynamical models of the fragmentation process. The latter refers largely to the handling of radiative transfer in three dimensional (3D) hydrodynamical models, which controls heating and cooling processes in gravitationally unstable disks, and hence dense clump formation. A suite of models using the β cooling approximation is presented here. The initial disks have masses of 0.091 $M_\odot$ and extend from 4 to 20 AU around a 1 $M_\odot$ protostar. The initial minimum Toomre Q_i values range from 1.3 to 2.7, while β ranges from 1 to 100. We show that the choice of Q_i is equal in importance to the β value assumed: high Q_i disks can be stable for small β, when the initial disk temperature is taken as a lower bound, while low Q_i disks can fragment for high β. These results imply that the evolution of disks toward low Q_i must be taken into account in assessing disk fragmentation possibilities, at least in the inner disk, i.e., inside about 20 AU. The models suggest that if low Q_i disks can form, there should be an as yet largely undetected population of gas giants orbiting G dwarfs between about 6 AU and 16 AU.

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https://home.dtm.ciw.edu/users/boss/ftp/beta-cooling.pdf

Trigonometric distance and proper motions of H2O maser bowshocks in AFGL 5142

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We present the results of multi-epoch VLBI observations of water masers in the AGFL 5142 massive star forming region. We measure an annual parallax of $\pi = 0.467 \pm 0.010$ mas, corresponding to a source distance of $D = 2.14^{+0.051}_{-0.049}$ kpc. Proper motion and line of sight velocities reveal the 3D kinematics of masers in this region, most of which associate with millimeter sources from the literature. In particular we find remarkable bipolar bowshocks expanding from the

most massive member, AFGL 5142 MM1, which are used to investigate the physical properties of its protostellar jet. We attempt to link the known outflows in this region to possible progenitors by considering a precessing jet scenario and we discuss the episodic nature of ejections in AFGL 5142.

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Chasing disks around O-type (proto)stars: Evidence from ALMA observations

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Circumstellar disks around massive stars could mediate the accretion onto the star from the infalling envelope, as well as minimise the effects of radiation pressure. Despite such a crucial role, only few convincing candidates have been provided for disks around deeply embedded O-type (proto)stars.
In order to establish whether disk-mediated accretion is the formation mechanism for the most massive stars, we have searched for circumstellar, rotating disks around a limited sample of 6 luminous ($>10^5$ $L_\odot$) young stellar objects. These have been selected in such a way as to maximize the likelihood of association with disk+jet systems, based on their IR and radio properties.
We used ALMA with $\sim0\overset{''}{.}2$ resolution to observe a large number of molecular lines, typical of hot molecular cores. In this paper we limit our analysis to two disk tracers (methyl cyanide, CH_3CN, and its isotopologue $^{13}CH_3CN$), and an outflow tracer (silicon monoxide, SiO).

We reveal many cores, although their number depends dramatically on the target. We focus on the cores that present prominent molecular line emission. In 6 of these a velocity gradient is seen across the core, with three cases showing evidence of Keplerian-like rotation. The SiO data reveal clear but poorly collimated bipolar outflow signatures towards two objects only. This can be explained if real jets are rare (perhaps short lived) in very massive objects and/or stellar multiplicity significantly affects the outflow structure. For all cores with velocity gradients, the velocity field is analysed through position–velocity plots to establish whether the gas is undergoing rotation with $v_{\rm rot} \propto R^{-\alpha}$, as expected for Keplerian-like disks.
Our results suggest that in 3 objects we are observing rotation in circumstellar disks, with 3 more tentative cases, and 1 core where no evidence for rotation is found. In all cases but one, we find that the gas mass is less than the mass of any embedded O-type star, consistent with the (putative) disks undergoing Keplerian-like rotation. With the caveat of low-number statistics, we conclude that the disk detection rate could be sensitive to the evolutionary stage of the YSO. In young, deeply embedded sources, the evidence for disks could be weak because of confusion with the surrounding envelope, while in the most evolved sources the *molecular* component of the disk could have already been dispersed. Only in those objects that are at an intermediate stage of the evolution, the molecular disk would be sufficiently prominent and relatively less embedded to be detectable by mm/submm observations.

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Growth of a massive young stellar object fed by a gas flow from a companion gas clump

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We present a Submillimeter Array (SMA) observation towards the young massive double-core system G350.69-0.49. This system consists of a northeast (NE) diffuse gas Bubble and a southwest (SW) massive young stellar object (MYSO), both clearly seen in the Spitzer images. The SMA observations reveal a gas flow between the NE Bubble and the SW MYSO in a broad velocity range from 5 to 30 km/s with respect to the system velocity. The gas flow is well confined within the interval between the two objects, and traces a significant mass transfer from the NE gas Bubble to the SW massive core. The transfer flow can supply the material accreted onto the SW MYSO at a rate of $4.2 \times 10^{-4}\ M_\odot$ year^{-1}. The whole system therefore suggests a mode for the mass growth in MYSO from a gas transfer flow launched from its companion gas clump, despite that the driving mechanism of the transfer flow is not yet fully determined from the current data.

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Sharpless-76E: Astrometry and Outflows in a Protostellar Cluster

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Using VLBI Exploration of Radio Astrometry (VERA), we have conducted multi-epoch observations of the H_2O masers associated with Sharpless 76E. The measured annual parallax is 0.521±0.024 mas corresponding to the distance of $1.92^{+0.09}_{-0.08}$ kpc. From the parallax measurement, we obtained the peculiar motion of Sh2-76E MM1 (U_{MM1}, V_{MM1}, W_{MM1}) to be (−9±3, 10±4, 6±4) km/s, and Sh2-76E MM2 (U_{MM2}, V_{MM2}, W_{MM2}) to be (−5±12, 3±14, −21±22) km/s, where U, V, and W are directed toward the Galactic center, in the direction of Galactic rotation and toward the Galactic north pole, respectively. The internal motion of the H_2O masers trace 2 separate bipolar outflows, one associated with Sh2-76E MM1 and the other with Sh2-76E MM2. The spectral energy distribution (SED) of Sh76E MM1 suggests it to be a class I YSO. We have only limited data points for the SED fit of Sh2-76E MM2, therefore can only speculate it to be probably a class II based on its comparative *K*-band and *H*-band magnitudes.

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Class II 6.7 GHz Methanol Maser Association with Young Massive Cores Revealed by ALMA

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We explored the implication of the association (or lack of it) of 6.7 GHz class II methanol (ch) masers with massive dense cores (MDCs) detected (within a sample of ATLASGAL selected infrared quiet massive clumps) at 0.9 mm with Atacama Large Millimeter/submillimeter array. We found 42 out of the 112 cores (37.5%) detected with the Atacama Compact Array (ACA) to be associated with 6.7 GHz ch masers. The lowest mass core with ch maser association is ∼ 12 $M_\odot$. The angular offsets of the ACA cores from the 6.7 GHz ch maser peak positions range from 0.″17 to 4.″79, with a median value of 2.″19. We found a weak correlation between the 0.9 mm continuum (MDCs) peak fluxes and the peak fluxes of their associated MMB 6.7 GHz ch masers. About 90% of the cores associated with 6.7 GHz ch masers have masses of > 40 $M_\odot$. The CH_3OH maser containing cores are candidates for embedded high mass protostellar objects in their earliest evolutionary stages. With our ACA 0.9 continuum data compared with the MMB 6.7 GHz ch maser survey, we have constrained the cores already housing a massive protostars based on their association with the radiatively pumped 6.7 GHz ch masers.

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Simultaneous low- and high-mass star formation in a massive protocluster: ALMA observations of G11.92-0.61

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We present 1.05 mm ALMA observations of the deeply embedded high-mass protocluster G11.92−0.61, designed to search for low-mass cores within the accretion reservoir of the massive protostars. Our ALMA mosaic, which covers an extent of ∼0.7 pc at sub-arcsecond (∼1400 au) resolution, reveals a rich population of 16 new millimetre continuum sources surrounding the three previously-known millimetre cores. Most of the new sources are located in the outer reaches of the accretion reservoir: the median projected separation from the central, massive (proto)star MM1 is ∼0.17 pc. The derived physical properties of the new millimetre continuum sources are consistent with those of low-mass prestellar and protostellar cores in nearby star-forming regions: the median mass, radius, and density of the new sources are 1.3 $M_\odot$, 1600 au, and n_{H_2} $\sim 10^7$ cm^{-3}. At least three of the low-mass cores in G11.92−0.61 drive molecular outflows, traced by high-velocity $^{12}CO(3\text{-}2)$ (observed with the SMA) and/or by H_2CO and CH_3OH emission (observed with ALMA). This finding, combined with the known outflow/accretion activity of MM1, indicates that high- and low-mass stars are forming (accreting) simultaneously within this protocluster. Our ALMA results are consistent with the predictions of competitive-accretion-type models in which high-mass stars form along with their surrounding clusters.

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The ATLASGAL survey: The sample of young massive cluster progenitors

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The progenitors of high-mass stars and clusters are still challenging to recognise. Only unbiased surveys, sensitive to compact regions of high dust column density, can unambiguously reveal such a small population of particularly massive and cold clumps. Here we study a flux limited sample of compact sources from the ATLASGAL survey to identify a sample of candidate progenitors of massive clusters in the inner Galaxy. Sensitive mid-infrared data at 21–24 μm from the WISE and MIPSGAL surveys were explored to search for embedded objects, and complementary spectroscopic data were used to investigate their stability and star formation activity. Based on such ancillary data we identify an unbiased sample of infrared-quiet massive clumps in the Galaxy that potentially represent the earliest stages of massive cluster formation. An important fraction of this sample consists of sources that have not been studied in detail before. Comparing their properties to clumps hosting more evolved embedded objects, we find that they exhibit similar physical properties in terms of mass and size, suggesting that infrared-quiet massive clumps are not only capable of forming high-mass stars, but likely also follow a single evolutionary track leading to the formation of massive clusters. The majority of the sources are not in virial-equilibrium, suggesting collapse on the clump scale. This is in line with the low number of infrared-quiet massive clumps and earlier findings that star formation, in particular for high-mass objects is a fast, dynamic process. We propose a scenario in which massive clumps start to fragment and collapse before their final mass is accumulated indicating that strong self-gravity and global collapse is needed to build up rich clusters and the most massive stars.

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Star Formation Activity in the molecular cloud G35.20−0.74: onset of cloud-cloud collision

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To probe the star-formation (SF) processes, we present results of an analysis of the molecular cloud G35.20−0.74 (hereafter MCG35.2) using multi-frequency observations. The MCG35.2 is depicted in a velocity range of 30-40 km s^{-1}. An almost horseshoe-like structure embedded within the MCG35.2 is evident in the infrared and millimeter images and harbors the previously known sites, ultra-compact/hyper-compact G35.20−0.74N H II region, Ap2-1, and Mercer 14 at its base. The site, Ap2-1 is found to be excited by a radio spectral type of B0.5V star where the distribution of 20 cm and Hα emission is surrounded by the extended molecular hydrogen emission. Using the *Herschel* 160-500 μm and photometric 1-24 μm data analysis, several embedded clumps and clusters of young stellar objects (YSOs) are investigated within the MCG35.2, revealing the SF activities. Majority of the YSOs clusters and massive clumps (500-4250 $M_\odot$) are seen toward the horseshoe-like structure. The position-velocity analysis of ^{13}CO emission shows a blue-shifted peak (at 33 km s^{-1}) and a red-shifted peak (at 37 km s^{-1}) interconnected by lower intensity intermediated velocity emission, tracing a broad bridge feature. The presence of such broad bridge feature suggests the onset of a collision between molecular components in the MCG35.2. A noticeable change in the H-band starlight mean polarization angles has also been observed in the MCG35.2, probably tracing the interaction between molecular components. Taken together, it seems that the cloud-cloud collision process has influenced the birth of massive stars and YSOs clusters in the MCG35.2.

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Fragmentation of vertically stratified gaseous layers: monolithic or coalescence-driven collapse

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We investigate, using 3D hydrodynamic simulations, the fragmentation of pressure-confined, vertically stratified, self-gravitating gaseous layers. The confining pressure is either thermal pressure acting on both surfaces, or thermal pressure acting on one surface and ram-pressure on the other. In the linear regime of fragmentation, the dispersion relation we obtain agrees well with that derived by Elmegreen & Elmegreen (1978), and consequently deviates from the dispersion relations based on the thin shell approximation Vishniac (1983) or pressure assisted gravitational instability Wünsch et al. (2010). In the non-linear regime, the relative importance of the confining pressure to the self-gravity is a crucial parameter controlling the qualitative course of fragmentation. When confinement of the layer is dominated by external pressure, self-gravitating condensations are delivered by a two-stage process: first the layer fragments into gravitationally bound but stable clumps, and then these clumps coalesce until they assemble enough mass to collapse. In contrast, when external pressure makes a small contribution to confinement of the layer, the layer fragments monolithically into gravitationally unstable clumps and there is no coalescence. This dichotomy persists whether the external pressure is thermal or ram. We apply these results to fragments forming in a shell swept up by an expanding HII region, and find that, unless the swept up gas is quite hot or the surrounding medium has low density, the fragments have low-mass ($\lesssim 3\ M_\odot$), and therefore they are unlikely to spawn stars that are sufficiently massive to promote sequential self-propagating star formation.

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Residual Gas & Dust Around Transition Objects and Weak T Tauri Stars

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Residual gas in disks around young stars can spin down stars, circularize the orbits of terrestrial planets, and whisk away the dusty debris that is expected to serve as a signpost of terrestrial planet formation. We have carried out a sensitive search for residual gas and dust in the terrestrial planet region surrounding young stars ranging in age from a few Myr to ∼10 Myr in age. Using high resolution 4.7 μm spectra of transition objects and weak T Tauri stars, we searched for weak continuum excesses and CO fundamental emission, after making a careful correction for the stellar contribution to the observed spectrum. We find that the CO emission from transition objects is weaker and located further from the star than CO emission from non-transition T Tauri stars with similar stellar accretion rates. The difference is possibly the result of chemical and/or dynamical effects (i.e., a low CO abundance or close-in low-mass planets). The weak T Tauri stars show no CO fundamental emission down to low flux levels (5×10^{-20}–10^{-18} W m^{-2}). We illustrate how our results can be used to constrain the residual disk gas content in these systems and discuss their potential implications for star and planet formation.

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Consistent SPH Simulations of Protostellar Collapse and Fragmentation

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We study the consistency and convergence of smoothed particle hydrodynamics (SPH), as a function of the interpolation parameters, namely the number of particles N, the number of neighbors n, and the smoothing length h, using simulations of the collapse and fragmentation of protostellar rotating cores. The calculations are made using a modified version of the GADGET-2 code that employs an improved scheme for the artificial viscosity and power-law dependences of n and h on N, as was recently proposed by Zhu et al., which comply with the combined limit $N \to \infty$, $h \to 0$, and $n \to \infty$ with $n/N \to 0$ for full SPH consistency, as the domain resolution is increased. We apply this realization to the "standard isothermal test case" in the variant calculated by Burkert & Bodenheimer and the Gaussian cloud model of Boss to investigate the response of the method to adaptive smoothing lengths in the presence of large density and pressure gradients. The degree of consistency is measured by tracking how well the estimates of the consistency integral relations reproduce their continuous counterparts. In particular, C^0 and C^1 particle consistency is demonstrated, meaning that the calculations are close to second-order accuracy. As long as n is increased with N, mass resolution also improves as the minimum resolvable mass $M_{\min} \sim n^{-1}$. This aspect allows proper calculation of small-scale structures in the flow associated with the formation and instability of protostellar disks around the growing fragments, which are seen to develop a spiral structure and fragment into close binary/multiple systems as supported by recent observations.

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Exploring molecular complexity with ALMA (EMoCA): Simulations of branched carbon-chain chemistry in Sgr B2(N)

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Context: Using millimeter wavelength data from the Atacama Large Millimeter/submillimeter Array (ALMA), the EMoCA spectral line survey recently revealed the presence of both the straight-chain (*normal*) and branched (*iso*) forms of propyl cyanide (C_3H_7CN) toward the Galactic Center star-forming source Sgr B2(N2). This was the first interstellar detection of a branched aliphatic molecule.
Aims: Through computational methods, we seek to explain the observed *i*:*n* ratio for propyl cyanide, and to predict the abundances of the four different forms of the homologous nitrile, butyl cyanide (C_4H_9CN). We also investigate whether other molecules will show a similar degree of branching, by modeling the chemistry of alkanes up to pentane (C_5H_{12}).
Methods: We use the coupled three-phase chemical kinetics model, *MAGICKAL*, to simulate the chemistry of the hot-core source Sgr B2(N2), using an updated chemical network that includes grain-surface/ice-mantle formation routes for branched nitriles and alkanes. The network explicitly considers radical species with an unpaired electron on either the primary or secondary carbon in a chain. We also include mechanisms for the addition of the cyanide radical, CN, to hydrocarbons with multiple bonds between carbon atoms, using activation energy barriers from the literature. We use the EMoCA survey data to search for the straight-chain form of butyl cyanide toward Sgr B2(N2).
Results: The observed *i*:*n* ratio for propyl cyanide is reproduced by the models, with intermediate to fast warm-up timescales providing the most accurate result. Butyl cyanide is predicted to show similar abundances to propyl cyanide, and to exhibit strong branching, with the *sec* form clearly dominant over all others. *Normal* and *iso*-butyl cyanide are expected to have similar abundances to each other, while the *tert* form is significantly less abundant. The addition of CN to acetylene and ethene is found to be important to the production of vinyl, ethyl, propyl, and butyl cyanide. The alkanes also show significant branching. We report a non-detection of n-C_4H_9CN toward Sgr B2(N2), with an abundance at least 1.7 times lower than that of n-C_3H_7CN. This value is within the range predicted by the chemical models.
Conclusions: The models indicate that the degree of branching rises with increasing molecular size. The efficiency of CN addition to unsaturated hydrocarbons boosts the abundances of nitriles in the model, and enhances the ratio of straight-to-branched molecule production. Other types of molecule may be less abundant, but show an even greater degree of branching. The predicted abundance of, in particular, s-C_4H_9CN, which at its peak is comparable to that of propyl cyanide, makes it a good candidate for future detection toward Sgr B2(N2).

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L1188: a promising candidate of cloud-cloud collisions triggering the formation of the low- and intermediate-mass stars

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We present a new large-scale (2°×2°) simultaneous ^{12}CO, ^{13}CO, and $C^{18}O$ (J=1−0) mapping of L1188 with the PMO 13.7-m telescope. Our observations have revealed that L1188 consists of two nearly orthogonal filamentary molecular clouds at two clearly separated velocities. Toward the intersection showing large velocity spreads, we find several bridging features connecting the two clouds in velocity, and an open arc structure which exhibits high excitation temperatures, enhanced ^{12}CO and ^{13}CO emission, and broad ^{12}CO line wings. This agrees with the scenario that the two clouds are colliding with each other. The distribution of young stellar object (YSO) candidates implies an enhancement of star formation in the intersection of the two clouds. We suggest that a cloud-cloud collision happened in L1188 about 1 Myr ago, possibly triggering the formation of low- and intermediate-mass YSOs in the intersection.

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Self-induced dust traps: overcoming planet formation barriers

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Planet formation is thought to occur in discs around young stars by the aggregation of small dust grains into much larger objects. The growth from grains to pebbles and from planetesimals to planets is now fairly well understood. The intermediate stage has however been found to be hindered by the radial-drift and fragmentation barriers. We identify a powerful mechanism in which dust overcomes both barriers. Its key ingredients are i) backreaction from the dust onto the gas, ii) grain growth and fragmentation, and iii) large-scale gradients. The pile-up of growing and fragmenting grains modifies the gas structure on large scales and triggers the formation of pressure maxima, in which particles are trapped. We show that these self-induced dust traps are robust: they develop for a wide range of disc structures, fragmentation thresholds and initial dust-to-gas ratios. They are favored locations for pebbles to grow into planetesimals, thus opening new paths towards the formation of planets.

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Placing the spotted T Tauri star LkCa 4 on an HR diagram

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Ages and masses of young stars are often estimated by comparing their luminosities and effective temperatures to pre-main sequence stellar evolution tracks, but magnetic fields and starspots complicate both the observations and evolution. To understand their influence, we study the heavily-spotted weak-lined T-Tauri star LkCa 4 by searching for spectral signatures of radiation originating from the starspot or starspot groups. We introduce a new methodology for constraining both the starspot filling factor and the spot temperature by fitting two-temperature stellar atmosphere models constructed from Phoenix synthetic spectra to a high-resolution near-IR IGRINS spectrum. Clearly discernable spectral features arise from both a hot photospheric component $T_{\rm hot} \sim 4100$ K and to a cool component $T_{\rm cool} \sim$ 2700–3000 K, which covers ∼80% of the visible surface. This mix of hot and cool emission is supported by analyses of the spectral energy distribution, rotational modulation of colors and of TiO band strengths, and features in low-resolution optical/near-IR spectroscopy. Although the revised effective temperature and luminosity make LkCa 4 appear much younger and lower mass than previous estimates from unspotted stellar evolution models, appropriate estimates will require the production and adoption of spotted evolutionary models. Biases from starspots likely afflict most fully convective young stars and contribute to uncertainties in ages and age spreads of open clusters. In some spectral regions starspots act as a featureless veiling continuum owing to high rotational broadening and heavy line-blanketing in cool star spectra. Some evidence is also found for an anti-correlation between the velocities of the warm and cool components.

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Nitrogen Fractionation in Protoplanetary Disks from the $H^{13}CN/HC^{15}N$ Ratio

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Nitrogen fractionation is commonly used to assess the thermal history of Solar System volatiles. With ALMA it is for the first time possible to directly measure $^{14}N/^{15}N$ ratios in common molecules during the assembly of planetary systems. We present ALMA observations of the $H^{13}CN$ and $HC^{15}N$ J=3–2 lines at 0.″5 angular resolution, toward a sample of six protoplanetary disks, selected to span a range of stellar and disk structure properties. Adopting a typical $^{12}C/^{13}C$ ratio of 70, we find comet-like $^{14}N/^{15}N$ ratios of 80–160 in 5/6 of the disks (3 T Tauri and 2 Herbig Ae disks) and lack constraints for one of the T Tauri disks (IM Lup). There are no systematic differences between T Tauri and Herbig Ae disks, or between full and transition disks within the sample. In addition, no correlation is observed between disk-averaged D/H and $^{14}N/^{15}N$ ratios in the sample. One of the disks, V4046 Sgr, presents unusually bright HCN isotopologue emission, enabling us to model the radial profiles of $H^{13}CN$ and $HC^{15}N$. We find tentative evidence of an increasing $^{14}N/^{15}N$ ratio with radius, indicating that selective photodissociation in the inner disk is important in setting the $^{14}N/^{15}N$ ratio during planet formation.

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On the formation of hot and warm Jupiters via secular high-eccentricity migration in stellar triples

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Hot Jupiters (HJs) are Jupiter-like planets orbiting their host star in tight orbits of a few days. They are commonly believed not to have formed in situ, requiring inwards migration towards the host star. One of the proposed migration scenarios is secular high-eccentricity or high-e migration, in which the orbit of the planet is perturbed to high eccentricity by secular processes, triggering strong tidal evolution and orbital migration. Previous theoretical studies have considered secular excitation in stellar binaries. Recently, a number of HJs have been observed in stellar triple systems. In the latter, the secular dynamics are much richer compared to stellar binaries, and HJs could potentially be formed more efficiently. Here, we investigate this possibility by modeling the secular dynamical and tidal evolution of planets in two hierarchical configurations in stellar triple systems. We find that the HJ formation efficiency is higher compared to stellar binaries, but only by at most a few tens of per cent. The orbital properties of the HJs formed in the simulations are very similar to HJs formed in stellar binaries, and similarly to studies of the latter we find no significant number of warm Jupiters. HJs are only formed in our simulations for triples with specific orbital configurations, and our constraints are approximately consistent with current observations. In future, this allows to rule out high-e migration in stellar triples if a HJ is detected in a triple grossly violating these constraints.

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An ALMA survey of DCN/$H^{13}CN$ and DCO^+/$H^{13}CO^+$ in protoplanetary disks

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The deuterium enrichment of molecules is sensitive to their formation environment. Constraining patterns of deuterium chemistry in protoplanetary disks is therefore useful for probing how material is inherited or reprocessed throughout the stages of star and planet formation. We present ALMA observations at $\sim 0\farcs6$ resolution of DCO^+, $H^{13}CO^+$, DCN, and $H^{13}CN$ in the full disks around T Tauri stars AS 209 and IM Lup, the transition disks around T Tauri stars V4046 Sgr and LkCa 15, and the full disks around Herbig Ae stars MWC 480 and HD 163296. We also present ALMA observations of HCN in the IM Lup disk. DCN, DCO^+, and $H^{13}CO^+$ are detected in all disks, and $H^{13}CN$ in all but the IM Lup disk. We find efficient deuterium fractionation for the sample, with estimates of disk-averaged DCO^+/HCO^+ and DCN/HCN abundance ratios ranging from ∼0.02–0.06 and ∼0.005–0.08, respectively, which is comparable to values reported for other ISM environments. The relative distributions of DCN and DCO^+ vary between disks, suggesting that multiple formation pathways may be needed to explain the diverse emission morphologies. In addition, gaps and rings observed in both $H^{13}CO^+$ and DCO^+ emission provide new evidence that DCO^+ bears a complex relationship with the location of the midplane CO snowline.

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An extraordinary outburst in the massive protostellar system NGC6334I-MM1: quadrupling of the millimeter continuum

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Based on sub-arcsecond ALMA and SMA 1.3 mm continuum images of the massive protocluster NGC6334I obtained in 2015 and 2008, we find that the dust emission from MM1 has increased by a factor of 4.0±0.3 during the intervening years, and undergone a significant change in morphology. The continuum emission from the other cluster members (MM2, MM4 and the UCHII region MM3=NGC6334F) has remained constant. Long term single-dish maser monitoring at HartRAO finds that multiple maser species toward NGC6334I flared beginning in early 2015, a few months before our ALMA observation, and some persist in that state. New ALMA images obtained in July-August 2016 at 1.1 and 0.87 mm confirm the changes with respect to SMA 0.87 mm images from 2008, and indicate that the (sub)millimeter flaring has continued for at least a year. The excess continuum emission, centered on the hypercompact HII region MM1B, is extended and elongated ($1.6'' \times 1.0'' \approx 2100 \times 1300$ au) with multiple peaks, suggestive of general heating of the surrounding subcomponents of MM1, some of which may trace clumps in a fragmented disk rather than separate protostars. In either case, these remarkable increases in maser and dust emission provide direct observational evidence of a sudden accretion event in the growth of a massive protostar yielding a sustained luminosity surge by a factor of 70 ± 20, analogous to the largest events in simulations by Meyer et al. (2017). This target provides an excellent opportunity to assess the impact of such a rare event on a protocluster over many years.

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Observational signatures of linear warps in circumbinary discs

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In recent years an increasing number of observational studies have hinted at the presence of warps in protoplanetary discs, however a general comprehensive description of observational diagnostics of warped discs was missing. We performed a series of 3D SPH hydrodynamic simulations and combined them with 3D radiative transfer calculations to study the observability of warps in circumbinary discs, whose plane is misaligned with respect to the orbital plane of the central binary. Our numerical hydrodynamic simulations confirm previous analytical results on the dependence of the warp structure on the viscosity and the initial misalignment between the binary and the disc. To study the observational signatures of warps we calculate images in the continuum at near-infrared and sub-millimetre wavelengths and in the pure rotational transition of CO in the sub-millimetre. Warped circumbinary discs show surface brightness asymmetry in near-infrared scattered light images as well as in optically thick gas lines at sub-millimetre wavelengths. The asymmetry is caused by self-shadowing of the disc by the inner warped regions, thus the strength of the asymmetry depends on the strength of the warp. The projected velocity field, derived from line observations, shows characteristic deviations, twists and a change in the slope of the rotation curve, from that of an unperturbed disc. In extreme cases even the direction of rotation appears to change in the disc inwards of a characteristic radius. The strength of the kinematical signatures of warps decreases with increasing inclination. The strength of all warp signatures decreases with decreasing viscosity.

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Resolving the fragmentation of high line-mass filaments with ALMA: the integral shaped filament in Orion A

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We study the fragmentation of the nearest high line-mass filament, the integral shaped filament (ISF, line-mass ∼400 $M_\odot$ pc^{-1}) in the Orion A molecular cloud. We have observed a 1.6 pc long section of the ISF with the Atacama Large Millimetre/submillimeter Array (ALMA) at 3 mm continuum emission, at a resolution of ∼3 *arcsec* (1 200 AU). We identify from the region 43 dense cores with masses about a solar mass. 60% of the ALMA cores are protostellar and 40% are starless. The nearest neighbour separations of the cores do not show a preferred fragmentation scale; the frequency of short separations increases down to 1 200 AU. We apply a two-point correlation analysis on the dense core separations and show that the ALMA cores are significantly grouped at separations below ∼17 000 AU and strongly grouped below ∼6 000 AU. The protostellar and starless cores are grouped differently: only the starless cores group strongly below ∼6 000 AU. In addition, the spatial distribution of the cores indicates periodic grouping of the cores into groups of ∼30 000 AU in size, separated by ∼50 000 AU. The groups coincide with dust column density peaks detected by *Herschel*. These results show hierarchical, two-mode fragmentation in which the maternal filament periodically fragments into groups of dense cores. Critically, our results indicate that the fragmentation models for lower line-mass filaments (∼16 $M_\odot$ pc^{-1}) fail to capture the observed properties of the ISF. We also find that the protostars identified with *Spitzer* and *Herschel* in the ISF are grouped at separations below ∼17 000 AU. In contrast, young stars with disks do not show significant grouping. This suggests that the grouping of dense cores is partially retained over the protostar lifetime, but not over the lifetime of stars with disks. This is in agreement with a scenario where protostars are ejected from the maternal filament by the slingshot mechanism, a model recently proposed for the ISF. The separation distributions of the dense cores and protostars may also provide an evolutionary tracer of filament fragmentation.

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Chemical fractionation of deuterium in the protosolar nebula

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Understanding gas-grain chemistry of deuterium in star-forming objects may help to explain their history and present state. We aim to clarify how processes in ices affect the deuterium fractionation. In this regard, we investigate a Solar-mass protostellar envelope using an astrochemical rate-equation model that considers bulk-ice chemistry. The results show a general agreement with the molecular D/H abundance ratios observed in low-mass protostars. The simultaneous processes of ice accumulation and rapid synthesis of HD on grain surfaces in the prestellar core hampers the deuteration of icy species. The observed very high D/H ratios exceeding 10 per cent, i.e., super-deuteration, are reproduced for formaldehyde and dimethyl ether, but not for other species in the protostellar envelope phase. Chemical transformations in bulk ice lower D/H ratios of icy species and do not help explaining the super-deuteration. In the protostellar phase, the D_2O/HDO abundance ratio was calculated to be higher than the HDO/H_2O ratio owing to gas-phase chemistry. Species that undergo evaporation from ices have high molecular D/H ratio and a high gas-phase abundance.

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The transiting dust clumps in the evolved disk of the Sun-like UXor RZ Psc

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RZ Psc is a young Sun-like star, long associated with the UXor class of variable stars, which is partially or wholly dimmed by dust clumps several times each year. The system has a bright and variable infrared excess, which has been interpreted as evidence that the dimming events are the passage of asteroidal fragments in front of the host star. Here, we present a decade of optical photometry of RZ Psc and take a critical look at the asteroid belt interpretation. We show that the distribution of light curve gradients is non-uniform for deep events, which we interpret as possible evidence for an asteroidal fragment-like clump structure. However, the clumps are very likely seen above a high optical depth mid-plane, so the disk's bulk clumpiness is not revealed. While circumstantial evidence suggests an asteroid belt is more plausible than a gas-rich transition disk, the evolutionary status remains uncertain. We suggest that the rarity of Sun-like stars showing disk-related variability may arise because i) any accretion streams are transparent, and/or ii) turbulence above the inner rim is normally shadowed by a flared outer disk.

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Constraints on the structure of hot exozodiacal dust belts

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Recent interferometric surveys of nearby main-sequence stars show a faint but significant near-infrared excess in roughly two dozen systems, i. e. around 10 % to 30 % of stars surveyed. This excess is attributed to dust located in the immediate vicinity of the star, the origin of which is highly debated. We used previously published interferometric observations to constrain the properties and distribution of this hot dust. Considering both scattered radiation and thermal reemission, we modelled the observed excess in nine of these systems. We find that grains have to be sufficiently absorbing to be consistent with the observed excess, while dielectric grains with pure silicate compositions fail to reproduce the observations. The dust should be located within $\sim 0.01 - 1\,au$ from the star depending on its luminosity. Furthermore, we find a significant trend for the disc radius to increase with the stellar luminosity. The dust grains are determined to be below $0.2 - 0.5\,\mu$m, but above $0.02 - 0.15\,\mu$m in radius. The dust masses amount to $(0.2-3.5)\times10^{-9}\,M_\oplus$. The near-infrared excess is probably dominated by thermal reemission, though a contribution of scattered light up to 35 % cannot be completely excluded. The polarisation degree predicted by our models is always below 5 %, and for grains smaller than $\sim$0.2 μm even below 1 %. We also modelled the observed near-infrared excess of another ten systems with poorer data in the mid-infrared. The basic results for these systems appear qualitatively similar, yet the constraints on the dust location and the grain sizes are weaker.

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Cold CO gas in the envelopes of FU Orionis-type young eruptive stars

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FUors are young stellar objects experiencing large optical outbursts due to highly enhanced accretion from the circumstellar disk onto the star. FUors are often surrounded by massive envelopes, which play a significant role in the outburst mechanism. Conversely, the subsequent eruptions might gradually clear up the obscuring envelope material and drive the protostar on its way to become a disk-only T Tauri star. Here we present an APEX ^{12}CO and ^{13}CO survey of eight southern and equatorial FUors. We measure the mass of the gaseous material surrounding our targets. We locate the source of the CO emission and derive physical parameters for the envelopes and outflows, where detected. Our results support the evolutionary scenario where FUors represent a transition phase from envelope-surrounded protostars to classical T Tauri stars.

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Analysis of Low Excitation HDO Transitions toward the High-mass Star-forming Regions G34.26+0.15, W51e$_1$/e$_2$ and W49N

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We present observations of the ground state $1_{0,1}$–$0_{0,0}$ rotational transition of HDO at 464.925 GHz and the $1_{1,0}$–$1_{0,1}$ transition at 509.292 GHz toward the three high-mass star forming regions: G34.26+0.15, W49N and W51e$_1$/e$_2$, carried out with the Caltech Submillimeter Observatory. For the first time, the latter transition is observed from the ground. The spectra are modeled, together with observations of higher-energy HDO transitions, as well as submillimeter dust continuum fluxes from the literature, using a spherically symmetric radiative transfer model to derive the radial distribution of the HDO abundance in the target sources. The abundance profile is divided into an inner hot core region, with kinetic temperatures higher than 100 K and a cold outer envelope with lower kinetic temperatures. The derived HDO abundance with respect to H_2 is (0.3–3.7)$\times10^{-8}$ in the hot inner region ($T > 100$ K) and (7.0–10.0)$\times10^{-11}$ in the cold outer envelope. We also used two $H_2^{18}O$ fundamental transitions to constrain the H_2O abundances in the outer ennvelopes. The HDO/H_2O ratios in these cold regions are found to be (1.8–3.1)$\times10^{-3}$ and are consequently higher than in the hot inner regions of these sources.

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The dependence of protostar formation on the geometry and strength of the initial magnetic field

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We report results from twelve simulations of the collapse of a molecular cloud core to form one or more protostars, comprising three field strengths (mass–to–flux ratios, μ, of 5, 10, and 20) and four field geometries (with values of the angle between the field and rotation axes, ϑ, of 0°, 20°, 45°, and 90°), using a smoothed particle magnetohydrodynamics method. We find that the values of both parameters have a strong effect on the resultant protostellar system and outflows. This ranges from the formation of binary systems when $\mu = 20$ to strikingly differing outflow structures for differing values of ϑ, in particular highly suppressed outflows when $\vartheta = 90°$. Misaligned magnetic fields can also produce warped pseudo–discs where the outer regions align perpendicular to the magnetic field but the innermost

region re–orientates to be perpendicular to the rotation axis. We follow the collapse to sizes comparable to those of first cores and find that none of the outflow speeds exceed 8 km s?1. These results may place constraints on both observed protostellar outflows, and also on which molecular cloud cores may eventually form either single stars and binaries: a sufficiently weak magnetic field may allow for disc fragmentation, whilst conversely the greater angular momentum transport of a strong field may inhibit disc fragmentation.

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A concordant scenario to explain FU Ori from deep centimeter and millimeter interferometric observations

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The aim of this work is to constrain properties of the disk around the archetype FU Orionis object, FU Ori, with as good as ∼25 au resolution. We resolved FU Ori at 29-37 GHz using the Karl G. Jansky Very Largy Array (JVLA) in the A-array configuration, which provided the highest possible angular resolution to date at this frequency band (∼0.″07). We also performed complementary JVLA 8-10 GHz observations, the Submillimeter Array (SMA) 224 GHz and 272 GHz observations, and compared with archival Atacama Large Millimeter Array (ALMA) 346 GHz observations to obtain the spectral energy distributions (SEDs). Our 8-10 GHz observations do not find evidence for the presence of thermal radio jets, and constrain the radio jet/wind flux to at least 90 times lower than the expected value from the previously reported bolometric luminosity-radio luminosity correlation. The emission at frequencies higher than 29 GHz may be dominated by the two spatially unresolved sources, which are located immediately around FU Ori and its companion FU Ori S, respectively. Their deconvolved radii at 33 GHz are only a few au, which is two orders of magnitude smaller in linear scale than the gaseous disk revealed by the previous Subaru-HiCIAO 1.6 μm coronagraphic polarization imaging observations. We are struck by the fact that these two spatially compact sources contribute to over 50% of the observed fluxes at 224 GHz, 272 GHz, and 346 GHz. The 8-346 GHz SEDs of FU Ori and FU Ori S cannot be fit by constant spectral indices (over frequency), although we cannot rule out that it is due to the time variability of their (sub)millimeter fluxes. The more sophisticated models for SEDs considering the details of the observed spectral indices in the millimeter bands suggest that the >29 GHz emission is contributed by a combination of free-free emission from ionized gas, and thermal emission from optically thick and optically thin dust components. We hypothesize that dust in the innermost parts of the disks ($\lesssim$0.1 au) has been sublimated, and thus the disks are no more well shielded against the ionizing photons. The estimated overall gas and dust mass based on SED modeling,

can be as high as a fraction of a solar mass, which is adequate for developing disk gravitational instability. ur present explanation for the observational data is that the massive inflow of gas and dust due to disk gravitational instability or interaction with a companion/intruder, was piled up at the few au scale due to the development of a deadzone with negligible ionization. The piled up material subsequently triggered the thermal instability and the magnetorotational instability when the ionization fraction in the inner sub-au scale region exceeded a threshold value, leading to the high protostellar accretion rate.

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Can the removal of molecular cloud envelopes by external feedback affect the efficiency of star formation?

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We investigate how star formation efficiency can be significantly decreased by the removal of a molecular cloud's envelope by feedback from an external source. Feedback from star formation has difficulties halting the process in dense gas but can easily remove the less dense and warmer envelopes where star formation does not occur. However, the envelopes can play an important role keeping their host clouds bound by deepening the gravitational potential and providing a constraining pressure boundary. We use numerical simulations to show that removal of the cloud envelopes results in all cases in a fall in the star formation efficiency (SFE). At 1.38 free-fall times our 4 pc cloud simulation experienced a drop in the SFE from 16 to six percent, while our 5 pc cloud fell from 27 to 16 per cent. At the same time, our 3 pc cloud (the least bound) fell from an SFE of 5.67 per cent to zero when the envelope was lost. The star formation efficiency per free-fall time varied from zero to ≈ 0.25 according to α, defined to be the ratio of the kinetic plus thermal to gravitational energy, and irrespective of the absolute star forming mass available. Furthermore the fall in SFE associated with the loss of the envelope is found to even occur at later times. We conclude that the SFE will always fall should a star forming cloud lose its envelope due to stellar feedback, with less bound clouds suffering the greatest decrease.

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A study of singly deuterated cyclopropenylidene c-C_3HD in protostar IRAS 16293−2422

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Cyclic-C_3HD (c-C_3HD) is a singly deuterated isotopologue of c-C_3H_2, which is one of the most abundant and widespread molecules in our Galaxy. We observed IRAS 16293−2422 in the 3 mm band with a single frequency setup using the EMIR heterodyne 3 mm receiver of the IRAM 30m telescope. We observed seven lines of c-C_3HD and three lines of c-C_3H_2. Observed abundances are compared with astrochemical simulations using the NAUTILUS gas-grain chemical model. Our results clearly show that c-C_3HD can be used as an important supplement for studying chemistry and physical conditions for cold environments. Assuming that the size of the protostellar envelope is 3000 AU and same excitation temperatures for both c-C_3H_2 and c-C_3HD, we obtain a deuterium fraction of 14^{+4}_{-3}%.

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The first 40 million years of circumstellar disk evolution: the signature of terrestrial planet formation

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We characterize the first 40 Myr of evolution of circumstellar disks through a unified study of the infrared properties of members of young clusters and associations with ages from 2 Myr up to ∼40 Myr: NGC 1333, NGC 1960, NGC 2232, NGC 2244, NGC 2362, NGC 2547, IC 348, IC 2395, IC 4665, Chamaeleon I, Orion OB1a and OB1b, Taurus, the β Pictoris Moving Group, ρ Ophiuchi, and the associations of Argus, Carina, Columba, Scorpius-Centaurus, and Tucana-Horologium. Our work features: 1.) a filtering technique to flag noisy backgrounds, 2.) a method based on the probability distribution of deflections, P(D), to obtain statistically valid photometry for faint sources, and 3.) use of the evolutionary trend of transitional disks to constrain the overall behavior of bright disks. We find that the fraction of disks three or more times brighter than the stellar photospheres at 24 μm decays relatively slowly initially and then much more rapidly by ∼10 Myr. However, there is a continuing component until ∼35 Myr, probably due primarily to massive clouds of debris generated in giant impacts during the oligarchic/chaotic growth phases of terrestrial planets. If the contribution from primordial disks is excluded, the evolution of the incidence of these oligarchic/chaotic debris disks can be described empirically by a log-normal function with the peak at 12–20 Myr, including ∼13% of the original population, and with a post-peak mean duration of 10–20 Myr.

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Outflows, infall and evolution of a sample of embedded low-mass protostars. The William Herschel Line Legacy (WILL) survey

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We present spectroscopic observations in H_2O, CO and related species with *Herschel* HIFI and PACS, as well as ground-based follow-up with the JCMT and APEX in CO, HCO^+ and isotopologues, of a sample of 49 nearby ($d < 500$ pc) candidate protostars. These data are used to study the outflow and envelope properties of these sources. We also compile their continuum SEDs in order to constrain their physical properties. Water emission is dominated by shocks associated with the outflow, rather than the cooler, slower entrained outflowing gas probed by ground-based CO observations. These shocks become less energetic as sources evolve from Class 0 to Class I. The fraction of mass in the outflow relative to the total envelope (i.e. $M_{\rm out}/M_{\rm env}$) remains broadly constant between Class 0 and I. The median value (∼1%) is consistent with a core to star formation efficiency on the order of 50% and an outflow duty cycle on the order of 5%. Entrainment efficiency, as probed by $F_{\rm CO}/\dot{M}_{\rm acc}$, is also invariant with source properties and evolutionary stage. The median value (6.3 km s^{-1}) suggests an entrainment efficiency of between 30 and 60% if the wind is launched at ∼1 AU. L[O I] is strongly correlated with $L_{\rm bol}$ but not with $M_{\rm env}$, while low-J CO is more closely correlated with the latter than the former. This suggests that [O I] traces the present-day accretion activity while CO traces time-averaged accretion over the dynamical timescale of the outflow. L[O I] does not vary from Class 0 to Class I, unlike CO and H_2O. This is likely due to the ratio of atomic to molecular gas in the wind increasing as the source evolves, balancing out the decrease in mass accretion rate. Infall signatures are detected in HCO^+ and H_2O in a few sources.

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Supernova enrichment of planetary systems in low-mass star clusters

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The presence and abundance of short lived radioisotopes (SLRs) ^{26}Al and ^{60}Fe in chondritic meteorites implies that the Sun formed in the vicinity of one or more massive stars that exploded as supernovae (SNe). Massive stars are more likely to form in massive star clusters (>1000 M$_\odot$) than lower mass clusters. However, photoevaporation of protoplanetary discs from massive stars and dynamical interactions with passing stars can inhibit planet formation in clusters with radii of ∼1 pc. We investigate whether low-mass (50 − 200 M$_\odot$) star clusters containing one or two massive stars are a more likely avenue for early Solar system enrichment as they are more dynamically quiescent.
We analyse N-body simulations of the evolution of these low-mass clusters and find that a similar fraction of stars experience supernova enrichment than in high mass clusters, despite their lower densities. This is due to two-body relaxation, which causes a significant expansion before the first supernova even in clusters with relatively low (100 stars pc^{-3}) initial densities. However, because of the high number of low mass clusters containing one or two massive stars, the absolute number of enriched stars is the same, if not higher than for more populous clusters. Our results show that direct enrichment of protoplanetary discs from supernovae occurs as frequently in low mass clusters containing one or two massive stars (>20 M$_\odot$) as in more populous star clusters (1000 M$_\odot$). This relaxes the constraints on the direct enrichment scenario and therefore the birth environment of the Solar System.

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Candidate Water Vapor Lines to Locate the H_2O Snowline through High-Dispersion Spectroscopic Observations II. The Case of a Herbig Ae Star

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Observationally measuring the location of the H_2O snowline is crucial for understanding the planetesimal and planet formation processes, and the origin of water on Earth. In disks around Herbig Ae stars ($T \sim 10,000$ K, $M \gtrsim 2.5$ $M_\odot$), the position of the H_2O snowline is further from the central star compared with that around cooler, and less massive T Tauri stars. Thus, the H_2O emission line fluxes from the region within the H_2O snowline are expected to be stronger. In this paper, we calculate the chemical composition of a Herbig Ae disk using chemical kinetics. Next, we calculate the H_2O emission line profiles, and investigate the properties of candidate water lines across a wide range of wavelengths (from mid-infrared to sub-millimeter) that can locate the position of the H_2O snowline. Those line identified have small Einstein A coefficients ($\sim10^{-6}$–10^{-3} s^{-1}) and relatively high upper state energies ($\sim$1000 K). The total fluxes tend to increase with decreasing wavelengths. We investigate the possibility of future observations (e.g., ALMA, SPICA/SMI-HRS) to locate the position of the H_2O snowline. Since the fluxes of those identified lines from Herbig Ae disks are stronger than those from T Tauri disks, the possibility of a successful detection is expected to increase for a Herbig Ae disk.

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Multi-Color Simultaneous Photometry of the T-Tauri Star Having A Planetary Candidate CVSO 30

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We present three-band simultaneous observations of a weak-line T-Tauri star CVSO 30 (PTFO 8-8695), which is one of the youngest objects having a candidate transiting planet. The data were obtained with the Multicolor Simultaneous Camera for studying Atmospheres of Transiting exoplanets (MuSCAT) on the 188 cm telescope at Okayama Astrophysical Observatory in Japan. We observed the fading event in the g'_2-, r'_2-, and $z_{\mathrm{s},2}$-bands simultaneously. As a result, we find a significant wavelength dependence of fading depths of about 3.1%, 1.7%, 1.0% for the g'_2-, r'_2-, and $z_{\mathrm{s},2}$-bands, respectively. A cloudless H/He dominant atmosphere of a hot Jupiter cannot explain this large wavelength dependence. Additionally, we rule out a scenario by the occultation of the gravity-darkened host star. Thus our result is in favor of the fading origin as circumstellar dust clump or occultation of an accretion hotspot.

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Turbulence and star formation efficiency in molecular clouds: solenoidal versus compressive motions in Orion B

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The nature of turbulence in molecular clouds is one of the key parameters that control star formation efficiency: compressive motions, as opposed to solenoidal motions, can trigger the collapse of cores, or mark the expansion of HII regions. We try to observationally derive the fractions of momentum density ($\rho\nu$) contained in the solenoidal and compressive modes of turbulence in the Orion B molecular cloud and relate these fractions to the star formation efficiency in the cloud. The implementation of a statistical method developed by Brunt & Federrath (2014), applied to a ^{13}CO(J=1–0) datacube obtained with the IRAM-30m telescope, allows us to retrieve 3-dimensional quantities from the projected quantities provided by the observations, yielding an estimate of the compressive versus solenoidal ratio in various regions of the cloud. Despite the Orion B molecular cloud being highly supersonic (mean Mach number $\sim$ 6), the fractions of motion in each mode diverge significantly from equipartition. The cloud's motions are on average mostly solenoidal (excess $> 8\%$ with respect to equipartition), which is consistent with its low star formation rate. On the other hand, the motions around the main star-forming regions (NGC 2023 and NGC 2024) prove to be strongly compressive. We have successfully applied to observational data a method that was so far only tested on simulations, and have shown that there can be a strong intra-cloud variability of the compressive and solenoidal fractions, these fractions being in turn related to the star formation efficiency. This opens a new possibility for star-formation diagnostics in galactic molecular clouds.

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Velocity Anisotropy in Self-Gravitating Molecular Clouds. I: Simulation

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The complex interplay between turbulence, magnetic fields, and self-gravity leads to the formation of molecular clouds out of the diffuse interstellar medium (ISM). One avenue of studying this interplay is by analyzing statistical features derived from observations, where the interpretation of these features is greatly facilitated by comparisons with numerical simulations. Here we focus on the statistical anisotropy present in synthetic maps of velocity centroid data, which we derive from three-dimensional magnetohydrodynamic simulations of a turbulent, magnetized, self-gravitating patch of ISM. We study how the orientation and magnitude of the velocity anisotropy correlate with the magnetic field and with the structures generated by gravitational collapse.
Motivated by recent observational constraints, our simulations focus on the supersonic (sonic Mach number $\mathcal{M} \approx 2-17$) but sub- to trans-alfvénic (alfvénic Mach number $\mathcal{M}_A \approx 0.2-1.2$) turbulence regime, and we consider clouds which are barely to mildly magnetically supercritical (mass-to-flux ratio equal to once or twice the critical value). Additionally we explore the impact of the turbulence driving mechanism (solenoidal or compressive) on the velocity anisotropy.
While we confirm previous findings that the velocity anisotropy generally aligns well with the plane-of-sky magnetic field, our inclusion of the effects of self-gravity reveals that in regions of higher column density, the velocity anisotropy may be destroyed or even reoriented to align with the gravitationally formed structures. We provide evidence that this effect is *not* necessarily due to the increase of $\mathcal{M}_A$ inside the high-density regions.

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Complex Organic Molecules tracing shocks along the outflow cavity in the high-mass protostar IRAS20126+4104

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We report on subarcsecond observations of complex organic molecules (COMs) in the high-mass protostar IRAS20126+4104 with the Plateau de Bure Interferometer in its most extended configurations. In addition to the simple molecules SO, HNCO and $H_2{}^{13}CO$, we detect emission from CH_3CN, CH_3OH, HCOOH, $HCOOCH_3$, CH_3OCH_3, CH_3CH_2CN, CH_3COCH_3, NH_2CN, and $(CH_2OH)_2$. SO and HNCO present a X-shaped morphology consistent with tracing the outflow cavity walls. Most of the COMs have their peak emission at the putative position of the protostar, but also show an extension towards the south(east), coinciding with an H_2 knot from the jet at about 800–1000 au from the protostar. This is especially clear in the case of $H_2{}^{13}CO$ and CH_3OCH_3. We fitted the spectra at representative positions for the disc and the outflow, and found that the abundances of most COMs are comparable at both positions, suggesting that COMs are enhanced in shocks as a result of the passage of the outflow. By coupling a parametric shock model to a large gas-grain chemical network including COMs, we find that the observed COMs should survive in the gas phase for about 2000 yr, comparable to the shock lifetime estimated from the water masers at the outflow position. Overall, our data indicate that COMs in IRAS20126+4104 may arise not only from the disc, but also from dense and hot regions associated with the outflow.

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The PAH Emission Characteristics of the Reflection Nebula NGC 2023

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We present 5-20 micron spectral maps of the reflection nebula NGC2023 obtained with the Infrared Spectrograph SL and SH modes on board the Spitzer Space Telescope which reveal emission from polycyclic aromatic hydrocarbons (PAHs), C60, and H2 superposed on a dust continuum. We show that several PAH emission bands correlate with each other and exhibit distinct spatial distributions revealing a spatial sequence with distance from the illuminating star. We explore the distinct morphology of the 6.2, 7.7 and 8.6 micron PAH bands and find that at least two spatially distinct components contribute to the 7–9 micron PAH emission in NGC2023. We report that the PAH features behave independently of the underlying plateaus. We present spectra of compact oval PAHs ranging in size from C_{66} to C_{210}, determined computationally using density functional theory, and investigate trends in the band positions and relative intensities as a function of PAH size, charge and geometry. Based on the NASA Ames PAH database, we discuss the 7–9 micron components in terms of band assignments and relative intensities. We assign the plateau emission to very small grains with possible contributions from PAH clusters and identify components in the 7–9 micron emission that likely originates in these structures. Based on the assignments and the observed spatial sequence, we discuss the photochemical evolution of the interstellar PAH family as they are more and more exposed to the radiation field of the central star in the evaporative flows associated with the PDRs in NGC2023.

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Accretion and outflow activity on the late phases of pre-main-sequence evolution. The case of RZ Piscium.

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RZ Psc is an isolated high-latitude post-T Tauri star that demonstrates a UX Ori-type photometric activity. The star shows very weak spectroscopic signatures of accretion, but at the same time possesses the unusual footprints of the wind in Na I D lines. In the present work we investigate new spectroscopic observations of RZ Psc obtained in 2014 during two observation runs. We found variable blueshifted absorption components (BACs) in lines of the other alcali metals, K I 7699 Å and Ca II IR triplet. We also confirmed the presence of a weak emission component in the Hα line, which allowed us to estimate the mass accretion rate on the star as $\dot{M} \leq 7 \cdot 10^{-12} M_{\odot} yr^{-1}$. We could not reveal any clear periodicity in the appearance of BACs in sodium lines. Nevertheless, the exact coincidence of the structure and velocities of the Na I D absorptions observed with the interval of about one year suggests that such a periodicity should exist.

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Candidate X-ray-Emitting OB Stars in the MYStIX Massive Star-Forming Regions

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Massive, O and early B-type (OB) stars remain incompletely catalogued in the nearby Galaxy due to high extinction, bright visible and infrared nebular emission in HII regions, and high field star contamination. These difficulties are alleviated by restricting the search to stars with X-ray emission. Using the X-ray point sources from the Massive Young star-forming complex Study in Infrared and X-rays (MYStIX) survey of OB-dominated regions, we identify 98 MYStIX candidate OB (MOBc) stars by fitting their 1–8 μm spectral energy distributions (SEDs) with reddened stellar atmosphere models. We identify 27 additional MOBc stars based on JHK_S photometry of X-ray stars lacking SED fitting. These candidate OB stars indicate that the current census of stars earlier than B1, taken across the 18 MYStIX regions studied, is less than 50% complete. We also fit the SEDs of 239 previously-published OB stars to measure interstellar extinction and bolometric luminosities, revealing six candidate massive binary systems and five candidate O-type (super)giants. As expected, candidate OB stars have systematically higher extinction than previously-published OB stars. Notable results for individual regions include: identification of the OB population of a recently discovered massive cluster in NGC 6357; an older OB association in the M17 complex; and new massive luminous O stars near the Trifid Nebula. In several relatively poorly-studied regions (RCW 38, NGC 6334, NGC 6357, Trifid, and NGC 3576), the OB populations may increase by factors of >2.

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http://astro.psu.edu/mystixfiles/ob-candidates

Odin observations of ammonia in the Sgr A +50 km/s Cloud and Circumnuclear Disk

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The Odin satellite is now into its sixteenth year of operation, much surpassing its design life of two years. One of the sources which Odin has observed in great detail is the Sgr A Complex in the centre of the Milky Way. The aims are to study the presence of NH3 in the Galactic Centre and spiral arms. Recently, Odin has made complementary observations of the 572 GHz NH3 line towards the Sgr A +50 km/s Cloud and Circumnuclear Disk (CND). Significant NH3 emission has been observed in both the +50 km/s Cloud and the CND. Clear NH3 absorption has also been detected in many of the spiral arm features along the line of sight from the Sun to the core of our Galaxy. The very large velocity width (80 km/s) of the NH3 emission associated with the shock region in the southwestern part of the CND may suggest a formation/desorption scenario similar to that of gas-phase H2O in shocks/outflows.

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https://arxiv.org/pdf/1701.02536

Detailed modeling of dust distribution in the disk of HD 142527

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We investigate the dust distribution in the crescent disk around HD 142527 based on the continuum emission at 890 μm obtained by ALMA Cycle 0. The map is divided into 18 azimuthal sectors, and the radial intensity profile in each sector is reproduced with a 2D disk model. Our model takes account of scattering and inclination of the disk as well as the azimuthal dependence in intensity. When the dust is assumed to have the conventional composition and maximum size of 1 mm, the northwestern region ($PA = 329° - 29°$) cannot be reproduced. This is because the model intensity gets insensitive to the increase in surface density due to heavy self-scattering, reaching its ceiling much lower than the observed intensity. The ceiling depends on the position angle. When the scattering opacity is reduced by a factor of 10, the intensity distribution is reproduced successfully in all the sectors including those in the northwestern region. The best fit model parameters depend little on the scattering opacity in the southern region where the disk is optically thin. The contrast of dust surface density along PA is derived to be about 40, much smaller than the value for the cases of conventional opacities $(70 - 130)$. These results strongly suggest that the albedo is lower than considered by some reasons at least in the northwestern region.

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https://arxiv.org/pdf/1701.06706v1.pdf

Redistribution of CO at the Location of the CO Ice Line in evolving Gas and Dust Disks

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Context. Ice lines are suggested to play a significant role in grain growth and planetesimal formation in protoplanetary disks. Evaporation fronts directly influence the gas and ice abundances of volatile species in the disk and therefore the coagulation physics and efficiency and the chemical composition of the resulting planetesimals.
Aims. In this work we investigate the influence of the existence of the CO ice line on the particle growth and on the distribution of CO in the disk.
Methods. We include the possibility of tracking the CO content and/or other volatiles in particles and in the gas in our existing dust coagulation and disk evolution model and developed a method for evaporation and condensation of CO using the Hertz-Knudsen equation. Our model does not include fragmentation, yet, which will be part of further investigations.
Results. We find no enhanced grain growth just outside the ice line where the particle size is limited by radial drift. Instead we find a depletion of solid material inside the ice line which is solely due to evaporation of the CO. Such a depression inside the ice line may be observable and may help to quantify the processes described in this work. Furthermore, we find that the viscosity and diffusivity of the gas heavily influence the re-distribution of vaporized CO at the ice line and can lead to an increase in the CO abundance by up to a factors of a few in the region just inside the ice line. Depending on the strength of the gaseous transport mechanisms the position of the ice line in our model can change by up to 10 AU and consequently, the temperature at that location can range from 21 K to 23 K.

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http://arxiv.org/pdf/1701.02385

Radiative grain alignment in protoplanetary disks: Implications for polarimetric observations

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We apply the theory of radiative torque (RAT) alignment for studying protoplanetary disks around a T-Tauri star and perform 3D radiative transfer calculations to provide the expected maps of polarized radiation to be compared with observations, such as with ALMA. We revisit the issue of grain alignment for large grains expected in the protoplanetary disks and find that mm-sized grains at midplane do not align with the magnetic field as the Larmor precession timescale for such large grains becomes longer than the gaseous damping timescale. Hence, for these grains the RAT theory predicts that the alignment axis is determined by the grain precession with respect to the radiative flux. As a result, we expect that the polarization will be in the azimuthal direction for a face-on disk. It is also shown that if dust grains have superparamagnetic inclusions, magnetic field alignment is possible for (sub-)micron grains at the surface layer of disks, and this can be tested by mid-infrared polarimetric observations.

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http://arxiv.org/pdf/1701.02063

Accretion and Magnetic Reconnection in the Classical T Tauri Binary DQ Tau

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The theory of binary star formation predicts that close binaries ($a < 100$ au) will experience periodic pulsed accretion events as streams of material form at the inner edge of a circumbinary disk (CBD), cross a dynamically cleared gap, and feed circumstellar disks or accrete directly onto the stars. The archetype for the pulsed accretion theory is the eccentric, short-period, classical T Tauri binary DQ Tau. Low-cadence (∼daily) broadband photometry has shown brightening events near most periastron passages, just as numerical simulations would predict for an eccentric binary. Magnetic reconnection events (flares) during the collision of stellar magnetospheres near periastron could, however, produce the same periodic, broadband behavior when observed at a one-day cadence. To reveal the dominant physical mechanism seen in DQ Tau's low-cadence observations, we have obtained continuous, moderate-cadence, multiband photometry over 10 orbital periods, supplemented with 27 nights of minute-cadence photometry centered on four separate periastron passages. While both accretion and stellar flares are present, the dominant timescale and morphology of brightening events are characteristic of accretion. On average, the mass accretion rate increases by a factor of five near periastron, in good agreement with recent models. Large variability is observed in the morphology and amplitude of accretion events from orbit to orbit. We argue that this is due to the absence of stable circumstellar disks around each star, compounded by inhomogeneities at the inner edge of the CBD and within the accretion streams themselves. Quasiperiodic apastron accretion events are also observed, which are not predicted by binary accretion theory.

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https://arxiv.org/pdf/1612.02431

Grand-design Spiral Arms in a Young Forming Circumstellar Disk

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We study formation and long-term evolution of a circumstellar disk in a collapsing molecular cloud core using a resistive magnetohydrodynamic simulation. While the formed circumstellar disk is initially small, it grows as accretion continues, and its radius becomes as large as 200 au toward the end of the Class-I phase. A pair of grand-design spiral arms form due to gravitational instability in the disk, and they transfer angular momentum in the highly resistive disk. Although the spiral arms disappear in a few rotations as expected in a classical theory, new spiral arms form recurrently as the disk soon becomes unstable again by gas accretion. Such recurrent spiral arms persist throughout the Class-0 and I phases. We then perform synthetic observations and compare our model with a recent high-resolution observation of a young stellar object Elias 227, whose circumstellar disk has grand-design spiral arms. We find good agreement between our theoretical model and the observation. Our model suggests that the grand-design spiral arms around Elias 227 are consistent with material arms formed by gravitational instability. If such spiral arms commonly exist in young circumstellar disks, it implies that young circumstellar disks are considerably massive and gravitational instability is the key process of angular momentum transport.

Accepted by The Astrophysical Journal Letters

https://arxiv.org/pdf/1611.09361

Radio Monitoring of Protoplanetary Discs

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Protoplanetary disc systems observed at radio wavelengths often show excess emission above that expected from a simple extrapolation of thermal dust emission observed at short millimetre wavelengths. Monitoring the emission at radio wavelengths can be used to help disentangle the physical mechanisms responsible for this excess, including free-free emission from a wind or jet, and chromospheric emission associated with stellar activity. We present new results from a radio monitoring survey conducted with Australia Telescope Compact Array over the course of several years with observation intervals spanning days, months and years, where the flux variability of 11 T Tauri stars in the Chamaeleon and Lupus star forming regions was measured at 7 and 15 mm and 3 and 6 cm. Results show that for most sources are variable to some degree at 7 mm, indicating the presence of emission mechanisms other than thermal dust in some sources. Additionally, evidence of grain growth to cm-sized pebbles was found for some sources that also have signs of variable flux at 7 mm. We conclude that multiple processes contributing to the emission are common in T Tauri stars at 7 mm and beyond, and that a detection at a single epoch at radio wavelengths should not be used to determine all processes contributing to the emission.

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http://arxiv.org/pdf/1701.02049

Evidence of a substellar companion around a very young T Tauri star

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We present results from a Near Infrared multi-epoch spectroscopic campaign to detect a young low-mass companion to a T Tauri star. AS 205A is a late-type dwarf (≈K5) of ~ 1 $M_\odot$ that belongs to a triple system. Independent photometric surveys discovered that AS 205A has two distinct periods (P_1=6.78 and P_2=24.78 days) detected in the light curve that persist over several years. Period P_1 seems to be linked to the axial-rotation of the star and is caused by the presence of cool surface spots. Period P_2 is correlated with the modulation in AS 205A brightness (V) and red color (V-R), consistent with a gravitating object within the accretion disk. We here derive precise Near Infrared radial velocities to investigate the origin of period P_2 which is predicted to correspond to a cool source in a Keplerian orbit with a semi-major axis of ∼0.17 AU positioned close to the inner disk radius of 0.14 AU. The radial velocity variations of AS 205A were found to have a period of P $\approx$ 24.84 days and a semi-amplitude of 1.529 kms^{-1}. This result closely resembles the P $_2$ period in past photometric observations (P $\approx$ 24.78 days). The analysis of the cross-correlation function bisector has shown no correlation with the radial velocity modulations, strongly suggesting that the period is not controlled by stellar rotation. Additional activity indicators should however be explored in future surveys. Taking this into account we found that the presence of a substellar companion is the explanation that best fits the results. We derived an orbital solution for AS 205A and found evidence of a $m_2 \sin i \simeq 19.25$ M_{Jup} object in an orbit with moderate eccentricity of e $\simeq$ 0.34. If confirmed with future observations, preferably using a multiwavelength survey approach, this companion could provide interesting constraints on brown dwarf and planetary formation models.

Accepted by Astronomy and Astrophysics

[http://arxiv.org/pdf/1701.02713

Mid-infrared extinction and fresh silicate dust towards the Galactic Center

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We interpret the interstellar extinction observed towards the Galactic Center (GC) in the wavelength range $\lambda = 1-20\,\mu$m. Its main feature is the flat extinction at $3-8\,\mu$m whose explanation is still a problem for the cosmic dust models. We search for structure and chemical composition of dust grains that could explain the observed extinction. In contrast to earlier works we use laboratory measured optical constants and consider particles of different structure. We show that a mixture of compact grains of aromatic carbon and of some silicate is better suited for reproducing the flat extinction in comparison with essentially porous grains or aliphatic carbon particles. Metallic iron should be located inside the particle, i.e. cannot form layers on silicate grains as the extinction curves become then very peculiar. We find a model including aromatic carbonaceous particles and three-layered particles with an olivine-type silicate core, a thin very porous layer and a thin envelope of magnetite that provides a good (but still not perfect) fit to the observational data. We suggest that such silicate dust should be fresh, i.e. recently formed in the atmospheres of late-type stars in the central region of the Galaxy. We assume that this region has a radius of about 1 kpc and produces about a half of the observed extinction. The remaining part of extinction is caused by a "foreground" material being practically transparent at $\lambda = 4-8\,\mu$m.

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http://arxiv.org/pdf/1701.08823

An ALMA and MagAO Study of the Substellar Companion GQ Lup B

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Multi-wavelength observations provide a complementary view of the formation of young directly-imaged planet-mass companions. We report the ALMA 1.3 mm and Magellan adaptive optics (MagAO) Hα, i', z', and Y_S observations of the GQ Lup system, a classical T Tauri star with a 10–40 $M_{\rm jup}$ substellar companion at $\sim$110 AU projected separation. We estimate the accretion rates for both components from the observed Hα fluxes. In our 0.″05 resolution ALMA map, we resolve GQ Lup A's disk in dust continuum, but no signal is found from the companion. The disk is compact, with a radius of $\sim$22 AU, a dust mass of $\sim$6 Earth masses, an inclination angle of $\sim$56°, and a very flat surface density profile indicative of a radial variation in dust grain sizes. No gaps or inner cavity are found in the disk, so there is unlikely a massive inner companion to scatter GQ Lup B outward. Thus, GQ Lup B might have formed in situ via disk fragmentation or prestellar core collapse. We also show that GQ Lup A's disk is misaligned with its spin axis, and possibly with GQ Lup B's orbit. Our analysis on the tidal truncation radius of GQ Lup A's disk suggests that GQ Lup B's orbit might have a low eccentricity.

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http://arxiv.org/pdf/1701.07541

Molecular outflows: Explosive versus protostellar

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With the recent recognition of a second, distinctive class of molecular outflows, namely the explosive ones not directly connected to the accretion-ejection process in the star formation, a juxtaposition of the morphological and kinematic properties of both classes is warranted. By applying the same method used in Zapata et al. (2009), and using ^{12}CO(J=2–1) archival data from the Submillimeter Array (SMA), we contrast two well known explosive objects, Orion KL and DR21, to HH211 and DG Tau B, two flows representative of classical low-mass protostellar outflows. At the moment there are only two well established cases of explosive outflows, but with the full availability of ALMA we expect that more examples will be found in the near future. Main results are the largely different spatial distributions of the explosive flows, consisting of numerous narrow straight filament-like ejections with different orientations and in almost an isotropic configuration, the red with respect to the blueshifted components of the flows (maximally separated in protostellar, largely overlapping in explosive outflows), the very well-defined Hubble flow-like increase of velocity with distance from the origin in the explosive filaments versus the mostly non-organized CO velocity field in protostellar objects, and huge inequalities in mass, momentum and energy of the two classes, at least for the case of low-mass flows. Finally, all the molecular filaments in the explosive outflows point back to approximately a central position i.e. the place where its "exciting source" was located, contrary to the bulk of the molecular material within the protostellar outflows.

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http://arxiv.org/pdf/1701.07113

Angular Momentum in Disk Wind Revealed in the Young Star MWC349A

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Disk winds are thought to play a critical role in star birth. As winds extract excess angular momentum from accretion disks, matter in the disk can be transported inward to the star to fuel mass growth. However, the observational evidence of wind carrying angular momentum has been very limited. We present Submillimeter Array (SMA) observations of the young star MWC349A in the H26α and H30α recombination lines. The high signal-to-noise ratios made possible by the maser emission process allow us to constrain the relative astrometry of the maser spots to a milli-arcsecond precision. Previous observations of the H30α line with the SMA and the Plateau de Bure interferometer (PdBI) showed that masers are distributed in the disk and wind. Our new high resolution observations of the H26α line reveal differences in spatial distribution from that of the H30α line. H26α line masers in the disk are excited in a thin annulus with a radius of about 25 AU, while the H30α line masers are formed in a slightly larger annulus with a radius of 30 AU. This is consistent with expectations for maser excitation in the presence of an electron density variation of approximately R^{-2}. In addition, the H30α and H26α line masers arise from different parts in the wind. This difference is also expected from the maser theory. The wind component of both masers exhibits line-of-sight velocities that closely follow a Keplerian law. This result provides strong evidence that the disk wind extracts significant angular momentum and thereby facilitating mass accretion in the young star.

Accepted by the Astrophysical Journal

http://arxiv.org/pdf/1702.02975

Abstracts of recently accepted major reviews

Formation of Exomoons: A Solar System Perspective

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Satellite formation is a natural by-product of planet formation. With the discovery of numerous extrasolar planets, it is likely that moons of extrasolar planets (exomoons) will soon be discovered. Some of the most promising techniques can yield both the mass and radius of the moon. Here, I review recent ideas about the formation of moons in our Solar System, and discuss the prospects of extrapolating these theories to predict the sizes of moons that may be discovered around extrasolar planets. It seems likely that planet-planet collisions could create satellites around rocky or icy planets which are large enough to be detected by currently available techniques. Detectable exomoons around gas giants may be able to form by co-accretion or capture, but determining the upper limit on likely moon masses at gas giant planets requires more detailed, modern simulations of these processes.

Accepted by Astronomical Review

http://arxiv.org/pdf/1701.02125

New Jobs

Postdoctoral Position in Stellar Astrophysics at Institute for Astronomy & Astrophysics Tübingen (Germany)

The Institute for Astronomy & Astrophysics of the University of Tübingen (IAAT) offers a postdoctoral position (E13 TV-L) in the area of observational stellar astrophysics within a new research group led by Beate Stelzer.

We seek an excellent candidate to work on the formation and evolution of low-mass stars and brown dwarfs with focus on protostellar disks and accretion/outflows, magnetic activity and rotation. The research group conducts multi-wavelength observations from the radio to the X-ray band using ground- and space-based instrumentation including top-level facilities such as ESO/VLT, XMM-Newton, Chandra, K2, VLA and Gaia. We participate in the future space missions eROSITA and Athena.

The IAAT presents a stimulating research environment, with research groups working on a variety of topics in theoretical, computational and observational astrophysics. The successful candidate will be involved in international collaborations and will be encouraged to participate in science teams of future astrophysical observing facilities. The applicant must have a PhD degree in astronomy or astrophysics and should have gained expertise in one or more of the scientific areas of the research group and its associated observing techniques (X-ray data analysis, optical spectroscopy/photometry, radio data analysis).

The appointment will be for an initial period of 2 years with a possible extension of 1 year. Salary will be according to grade E13 of the TV-L of the German public services. The application is expected to consist of a CV, publication list and brief (max. 2 pages) statement of previous research experience and current research interests. Two letters of recommendation should be arranged by the applicant to be sent separately to the email-address given below. Review of applications will start on March 15, 2017 and continue until the position is filled. The position is available immediately and the starting date as soon as possible.

The University of Tübingen wishes to enhance the share of women employed in research and teaching. In case of equal qualification preference will be given to applicants with disabilities.

Contact for application and further information: Beate Stelzer (stelzer@astro.uni-tuebingen.de)

The responsability for the employment lies with the administration of the University of Tübingen.

Postdoc in MHD Simulations of Star-Disk Interaction

The astrophysics group at the University of Exeter invites applications for a postdoctoral research position, to work with Prof. Sean Matt on theoretical studies of young stars interacting with accretion disks. The position is funded by a European Research Council grant (AWESoMeStars) and is initially for 3 years, with the possibility of extension, depending on progress and funding.

The overall project aims to develop a comprehensive, physical description of the rotation, magnetic activity, and environments of sun-like and low-mass stars. For this, understanding the pre-main-sequence phase is critical, but there remain major questions about the nature of mass and angular momentum flow around accreting, young stars. To tackle these questions, the successful applicant will use multi-dimensional magnetohydrodynamics (MHD) simulations to study the magnetic star-disk interaction. We are thus particularly interested in applicants with a strong background in computational and/or theoretical (magneto)hydrodynamics; prior work on star formation, accretion, outflows, or stellar rotation would be an additional asset.

The AWESoMeStars team currently consists of 4 researchers (including 2 PhD students, 1 postdoc) and will recruit one more PhD student and two more postdocs this year, working on various aspects of the project. We are embedded in the vibrant and highly successful astrophysics group at Exeter, a top-10 UK university located in the southwest of England. Substantial supercomputing resources and funding for computing equipment and travel will be available. There will also be the possibility to gain experience in mentoring and outreach.

Applicants must possess (or be near completion of) a relevant PhD. To apply, and for further information, use Exeter's online system by going to `https://jobs.exeter.ac.uk` and search for job reference P55841 in the "keywords" field. Applications should include a CV and a brief research statement (2 pages max) describing past work and future interest. In addition, please have 2 or 3 letters of recommendation sent to `s.matt@exeter.ac.uk`, with the applicant's name in the subject, before the **March 1st deadline**.

Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the Newsletter bounces back from an address for three consecutive months, the address is deleted from the mailing list.

Meetings

Kavli Workshop 'The migration issue: from protoplanets to supermassive black holes' May 22-24 2017, Cambridge UK

This workshop is motivated by the broad simlarities surrounding the theory of disc mediated migration on scales ranging from protoplanetary discs to galactic nuclei. Migration theory thus underpins our understanding of some of the most topical problems in contemporary astrophysics, i.e. the establishment of planetary system 'architecture' and the processes driving the merging of black holes.

We invite participants from both the protoplanetary disc and gravitational wave communities to attend this three day meeting which will address theory and numerical simulations of migration as well as its broader implications.We will also discuss new opportunities in both fields for observational calibration of the migration process (e.g. by observations using ALMA, SPHERE,GPI, LIGO....).

Abstracts for talks/posters should be submitted by 1 March 2017 via the on-line forms available at

http://www.ast.cam.ac.uk/meetings/2017/migration.issue.protoplanets.supermassive.black.holes

The number of participants is limited; we will inform applicants of the outcome of the selection process by mid March which will also mark the opening of on-line registration. We particularly encourage applications from junior researchers and can offer finanical support to those with limited funds.

EWASS 2017 Symposium 3: Comparing simulations and observations of the varying scales of star formation Prague, June 26-27, 2017

Abstract deadline is 8 March 2017 with late registration ending 26 June 2017.

Abstract submission and registration: http://eas.unige.ch/EWASS2017/

Symposium Webpage: http://eas.unige.ch/EWASS2017/session.jsp?id=S3

This Symposium is divided into two parts. The first part will review current efforts to observe star formation in the Galactic Centre, the Galactic plane and in nearby extra-galactic systems, as well as attempts to simulate star formation in all of these environments. The second part will confront a new problem posed by the vast amounts of data now being produced by both observations and simulations of Galactic star formation: how do we compare observations with simulations in a meaningful fashion that uses both types of data to their full potential? Many previous attempts to compare numerical simulations with observations have been relatively crude, often making use of the raw simulation output in the form of densities or temperatures, quantities that are not directly observable. A highly promising alternative technique is to use the simulation data to produce 'synthetic' observations of light that can be analysed in the same fashion as real observations. Synthetic observations in principle allow us to perform like-for-like comparisons between simulated and real sites of star formation. During part II of the Symposium, we aim to review current efforts (i) to produce synthetic observations while accounting for the limitations inherent in real telescopes and instruments, and (ii) to develop and apply statistical techniques for the objective and quantitative comparison of realistic synthetic observations with real observations of star formation on a variety of scales.

Some of the topics that will be discussed are: Star formation at the centre of the Galaxy, Surveys of the Galactic plane, Simulations of star formation on Galactic scales, Synthetic observations of simulations: establishing observational tests to discriminate models, Strengths and limitations of observational data, and Statistical tools for comparing simulations and observations.

We have several talk and poster slots available and encourage abstract submissions before the EWASS 2017 deadline of 8 March 2017.

Current confirmed invited speakers with more TBC: Volker Ossenkopf-Okada (Uni. Köln), Stella Offner (UMass)

SOC: David Eden (LJMU, co-chair), Simon Glover (Uni. Heidelberg, co-chair), Christine Koepferl (St. Andrews), Kathryn Kreckel (MPIA), Anaelle Maury (CEA-Irfu), Sarah Ragan (Cardiff), Stefanie Walch (Uni. Köln)

Gordon Research Conference Origins of Solar Systems: Making a Habitable Planet

The Gordon Conference on Origins of Solar Systems brings together a diverse group of scientists to discuss research at the frontier of understanding how planets and planetary systems form. Invited speakers from the fields of astronomy, astrophysics, cosmochemistry, planetary science, and geochemistry will present their latest findings. At this meeting discussions will take place with a focus on how the Earth and its analogs received their inventory of volatile compounds that provide the basis for a habitable world. Particular topics of discussion include the following. How new astronomical facilities, such as the Atacama Large Millimeter Array and infrared imaging systems, are transforming our knowledge of the evolution of gas and dust in protoplanetary disks and debris systems. How planetary building blocks are assembled and whether volatiles implanted during early phases survive inside their interior. Exploring the fate of volatiles supplied to a young terrestrial planet during the epoch of impacts and core formation. How the architecture of a solar system influences planetary assembly and volatile supply. What constraints meteorites and solar system bodies provide on the chemical and physical evolution during the phase of planet formation. Within this framework we will also discuss the growing knowledge of the exoplanet inventory with emphasis on what they might tell us about their formation and subsequent evolution.

This years meeting will include a Graduate Research Seminar. The Gordon Research Seminar on Origins of Solar Systems is a unique forum for graduate students, post-docs, and other scientists with comparable levels of experience and education to present and exchange new data and cutting edge ideas across the fields of astronomy, astrophysics, cosmochemistry, planetary science, and geochemistry.

This meeting will focus on promoting cross-disciplinary conversations, starting with a review talk to provide attendees with the background knowledge needed to get the most out of the GRS and subsequent GRC. The topics that will be explored include, but are not limited to, the characteristics of exoplanets, recent advancements in our understanding of the gas and dust in protoplanetary and debris disks, and the history of the solar system as revealed by small bodies. The meeting will also include a career panel driven by participants questions discussing career paths with both upcoming and senior faculty. Talks from graduate students and postdocs will be selected from submitted poster abstracts and we hope to make support available to as many participants as possible.

Meeting to be held:

June 17-18, 2017 GRS

June 18-23, 2017 GRC

at Mount Holyoke College, South Hadley, MA, USA

Application deadline

GRS: March 17, 2017 (for talk consideration), May 20, 2017 (for attendance)

GRC: May 21, 2017, please apply early as some meetings become oversubscribed.

https://www.grc.org/programs.aspx?id=12346

Current and Future Perspectives of Chemical Modelling in Astrophysics

July 17-19, 2017 – Hamburg, Germany

In the ALMA era it is fundamental to include chemistry and the related microphysics in computational studies aimed at understanding and probing the physical conditions of the different astrophysical environments. This requires to build accurate, well optimised, state-of-the-art models to be included in hydrodynamical simulations. It is then important to provide a platform connecting the different experts to stimulate an exchange of ideas, and to work towards a coherent understanding of chemical modelling in astrophysics.

This workshop aims at experts on the calculations and measurements of rates for chemical processes relevant in astrophysics, both in the gas phase as well as on dust, and astrophysicists who develop tools and/or employ chemistry and microphysics in hydrodynamical simulations of the interstellar medium.

The workshop will cover the following topics: - Computational Astrochemistry: Numerical Codes and Databases - Chemistry/Microphysics in Hydrodynamical Simulations - Modelling Observations - Gas/Dust phase processes: theory - Gas/Dust phase processes: experiments

Conference poster: www.hs.uni-hamburg.de/astromodel2017/flyer.pdf
More information and registration: http://www.hs.uni-hamburg.de/astromodel2017

Important dates:
January 30th, 2017: Opening of registration
May 1st, 2017: End of abstract submission
End of May, 2017: Announcement of the selected talks and posters
June 11th, 2017: End of registration

Invited Speakers: Stephanie Cazaux, Cecilia Ceccarelli, Paul Clark, David Neufeld, Dieter Gerlich, Troels Haugboelle, Guillermo Munoz-Caro, Dmitry Semenov, Alexander Tielens, Valentine Wakelam, Laurent Wiesenfeld, Simon Portegies Zwart

Scientific Organizing Committee: Robi Banerjee, Stefano Bovino, Paola Caselli, Daniele Galli, Tommaso Grassi Bastian Kortgen, Daniel Seifried, Dominik Schleicher, Wing-Fai Thi

Local Organizing Committee: Robi Banerjee, Stefano Bovino, Bastian Krtgen

Ages^2: Taking stellar ages to the next power

Elba, Italy – September 18-22, 2017

Program and deadlines web page: http://www.stsci.edu/institute/conference/ages2017

Registration and local information web page: http://agenda.infn.it/event/StellarAges2017

We are pleased to announce on behalf of our SOC a symposium devoted to stellar ages this fall. 'The Ages of Stars' was held as IAU Symposium 258 in Baltimore in 2008. Much progress has been made since then in the critical problem of estimating stellar ages. This second Ages meeting will focus on these major themes:

1. Pre-main sequence and very young stars, and the connection to the formation and early evolution of stars and planetary systems.
2. Solar-type and low-mass stars, and the connection to exoplanets.
3. Evolved stars and the connection to Galactic archaeology.
4. High-mass and intermediate-mass stars and the connection to clusters.
5. Ages of the oldest stars and the connection to the halo and accretion.
6. Stellar models and their limitations.

We are planning an in-depth week covering a broad range of topics related to stellar ages. Suggestions for topics and speakers are welcome; contact ages2017@stsci.edu. For registration information, contact stellarages2017@pi.infn.it. To receive updates on the symposium, send an e-mail to ages2017@stsci.edu.

For the SOC, the co-chairs:

David Soderblom, Space Telescope Science Institute - drs@stsci.edu
Scilla Degl'Innocenti, University of Pisa - scilla.deglinnocenti@unipi.it

Summary of Upcoming Meetings

Star Formation from Cores to Clusters
6 - 9 March 2017, Santiago, Chile
http://www.eso.org/sci/meetings/2017/star-formation2017.html

Astrochemistry VII - Through the Cosmos from Galaxies to Planets
20 - 24 March 2017, Puerto Varas, Chile
http://newt.phys.unsw.edu.au/IAUS332/

Formation and Dynamical Evolution of Exoplanets
26 - 31 March 2017, Aspen, USA
http://ciera.northwestern.edu/Aspen2017.php

Multi-Scale Star Formation
3 - 7 April 2017, Morelia, Mexico
http://www.irya.unam.mx/multi-scaleSF17/

The migration issue: from protoplanets to supermassive black holes
22 - 24 May 2017, Cambridge, UK
http://www.ast.cam.ac.uk/meetings/2017/migration.issue.protoplanets.supermassive.black.holes

Protoplanetary Disks and Planet Formation and Evolution
29 May - 23 June 2017, Garching bei München, Germany
http://www.munich-iapp.de/scientific-programme/programmes-2017/protoplanetary-disks/

Accretion, Differentiation and Early Evolution of Terrestrial Planets
29 May - 3 June 2017, Nice, France
https://www-n.oca.eu/morby/Accrete.html

Francesco's Legacy: Star Formation in Space and Time
6 - 9 June 2017, Firenze, Italy
http://www.arcetri.astro.it/sfst2017/

Gordon Research Seminar Origins of Solar Systems
17 - 18 June 2017, South Hadley, USA
https://www.grc.org/programs.aspx?id=17506

Gordon Research Conference Origins of Solar Systems: Making a Habitable Planet
18 - 23 June 2017, South Hadley, USA
https://www.grc.org/programs.aspx?id=12346

Comparing simulations and observations of the varying scales of star formation
26-27 June 2017, Prague, Czech Republic
http://eas.unige.ch/EWASS2017/session.jsp?id=S3

Current and Future Perspectives of Chemical Modelling in Astrophysics
17 - 19 July 2017, Hanburg, Germany
http://www.hs.uni-hamburg.de/astromodel2017

Ages^2: Taking stellar ages to the next power
18 - 22 September 2017, Elba, Italy
http://www.stsci.edu/institute/conference/ages2017

Planet Formation and Evolution 2017
25 - 27 September 2017, Jena, Germany
http://www.astro.uni-jena.de/~pfe2017