The Star Formation Newsletter

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

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Cover Picture
The Mon R2 star forming region is seen in the cover picture, which is a composite of optical images. The mostly embedded Mon R2 cluster is located towards the reddish region on the left edge, while blue reflection nebulae are seen around massive young stars. The distance to Mon R2 is approximately 830 pc. The molecular cloud associated with Mon R2 and pointing towards it is sculpted by numerous molecular outflows and by winds from massive stars.

Image courtesy Adam Block, Mt. Lemmon Sky-Center
http://www.caelumobservatory.com

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

Eta Carinae (η Car) is located in the Carina arm of the Milky Way, a hot bed of star formation. It is associated with the young Trumpler 16 cluster which has massive main sequence stars with estimated ages of 1 Myr and and abundance of low-mass PMS stars of 1-3 Myrs (e.g., Hur et al. 2012).

η Car, its interacting winds and historical ejecta, provide an unique astrophysical laboratory that permits addressing a multitude of questions ranging from stellar evolution, colliding winds, chemical enrichment, nebular excitation, to the formation of molecules and dust. Every 5.54 years, η Car changes from high excitation to several-months-long low excitation caused by modulation of the massive interacting winds due to a very eccentric binary orbit. The surrounding Homunculus (Figure 1) and Little Homunculus, thrown out in the 1840s Great Eruption and the 1890s Lesser Eruption, respond to the changing flux, providing clues to many physical phenomena of great interest to astrophysicists.

Some, but certainly not all of the pressing questions concerning η Car include:

1) How did the massive binary drive out ten to forty $M_\odot$, yet survive?

2) Which star experienced the Great Eruption: the current massive primary, the less massive secondary, a third, now absent star?

3) Nitrogen is very overabundant, with carbon and oxygen greatly depleted. Is this due entirely to the interrupted CNO-cycle or did molecule and dust formation contribute?

4) What is the dust that has formed? Is it alumina or silicon carbide, or metallic?

5) Why do we see emission and absorption lines of strontium, scandium and vanadium, elements not seen in the interstellar medium?

6) Are the winds stable or changing over extended intervals longer than the 5.54-year cycle?

7) Are conditions in the shocked winds such that molecules and dust continue to form?

For the past sixteen years, I have participated with many interested astronomers in conducting multiple observations and modelings of this intriguing system. Many papers, conference proceedings and even several monographs\footnote{A sub-sampling of reviews, conference proceedings and monographs includes: Davidson & Humphreys, 1997; Gull, Johansson & Davidson, 2001; Davidson & Humphreys, 2012} have been written about η Car. At conferences discussing massive stars and their final evolutionary stages, often η Car is the elephant in the room that some attendees would prefer to ignore. Crucial observations to test and improve current models are scheduled during the next several months as the η Car drops from the five-year-long high excitation state to a several month interval of low excitation. In this discussion, I show what is so intriguing about this system and why we call it an astrophysical laboratory that lends itself well to studies of massive stars in late stages of stellar evolution, massive, interacting winds, massive ejecta not yet mixed with the interstellar material, and reactions of material to relatively high density shocks, high radiation levels and high densities.

While observations prior to the early 1800s are limited, observers noted that η Car brightened to exceed Canopus in the southern sky in 1838, stayed relatively bright for two decades, but then faded below naked-eye visibility. While η Car went through a minor brightening in the 1890s it again faded (Smith & Frew, 2011). Since the 1940s, η Car has experienced a gradual brightening achieving naked eye visibility in the last decade (for current photometry, see http://etacar.fcaglp.unlp.edu.ar/, Fernandez-Lajus et al., 2009).

Many observers have been quite intrigued with η Car. Gaviola (1950,1953) studied both the structure and spectra in the 1940’s when astronomers noticed a gradual brightening that continues more or less to the present. Thackeray (1967) and Aller & Dunham (1966) obtained some of the first high dispersion spectra of the central source, identified many of the lines, described the broad and narrow profiles and noted changes in line profiles between observations approximately five years apart. Davidson et al. (1986) using ultraviolet spectra recorded by the \textit{International Ultraviolet Explorer} and visible spectra recorded by
the Cerro Tololo Inter-American Observatory Blanco Telescope, determined that nebular nitrogen was very over-abundant at the expense of carbon and oxygen. This suggested that within η Car is a very massive star capable of internal conduction leading to interruption of the CNO cycle leading to overproduction of nitrogen.

The central source is a massive binary whose periodicity was first noticed by Damineli (1996) through the 5.52-year periodic weakening of He I 10830Å emission accompanied with fading of other He I lines and disappearance of [Ar III]. Previous observers had suggested much longer periods, limited by the very sparse spectroscopic data taken over the previous century. Payne-Gaposchkin (1957) suggested a possible 16 year period; Zanella et al. (1984) surmised there to be a 17-year period. Further studies, summarized by Damineli et al. (2008) refined the period to 2024 ± 1.7 days (5.54 years). They noted that both broad and narrow components of many forbidden lines of [Ne III], [Ar III], [Fe III], [N II], [Fe II] and [Ni II] were modulated by the 5.54-year period. Ultimately this periodicity was found to be associated with the period of a massive binary with a highly eccentric orbit. The FUV radiation from the hot, less massive secondary plunges within one to two AU of the primary, well within the very extensive primary wind, thus modulating the FUV and X-ray emission. Damineli et al. (1998) defined the broad high ionization state associable with the lengthy time spent with the binary at large separation as most of the orbit is spent at distances close to apastron and the short low-ionization state associable with the rapid, very close passage across periastron.

Hillier et al. (2001, 2006) modeled the STIS spectra using CMFGEN and determined that the primary star, η Car A, is at least 100 M☉. Based on excitation studies of nearby emission blobs, Verner et al. (2002) and Mehner et al. (2010) placed estimates of 30 to 50 M☉ for the secondary η Car B.

2 The System

Today we see a massive Homunculus, so named by Gavilioli (1950) as the nebulosity had a humanoid appearance in seeing-limited photographic imagery. By the current decade, the Homunculus has an apparent size of 10″ × 20″ and with radial expansion velocities up at 600 km/s (Figure 1). With modern observatories and imaging spectrographs, spatially resolving structures within this ejecta prove to be quite feasible, thus enabling detailed studies of very different physical conditions within the ejecta. Smith (2006) used long-slit spectra obtained with the Phoenix spectrograph on Gemini South to determine the distance to be 2350 ± 50 pc. Exterior structures, seen primarily
in the red Hα+[N II] emission, also originated during the Great Eruption. Smith (2008) suggested that this material moves at space velocities between 3500 to 6000 km/s. Indeed kinetic energy expended during the Great Eruption of the 1840s must rival that of a weak supernova remnant. As the number of pseudo-supernova events in nearby galaxies accumulate, it becomes increasingly convincing that η Car is not unique, but rather the phenomenon that we have observed for nearly two centuries is a transient stage in the evolution of massive binary systems. This compels us to study η Car and its ejecta even more.

2.1 Winds and Nearby Ejecta

Emission line structures located close to η Car are spatially and spectrally resolvable, especially with the HST angular resolution of 0.1" (235 AU) and the many spectral modes of the STIS (Woodgate et al. 1998). Davidson et al. (1997) successfully proposed to use the STIS long slit capabilities to obtain spectra of the four point-like components first detected by Weigelt & Ebersberger (1986). While Weigelt A is the stellar η Car, the other three components are very bright, highly-excited, somewhat-extended, emission nebulae, located within hundreds of AU of η Car (see Figure 2). This led to a series of programs utilizing the spectral and spatial capabilities of HST with STIS that addressed the variability of η Car and the responses by the Weigelt blobs and other ejecta across the broad high ionization state and the brief low ionization state. The first series of observations captured spectra of η Car during the 1998.0 low state (binary system near periastron) and later observations in the first few years of the high state (Davidson et al. 1997; Gull et al. 1999; Davidson et al. 1999). A collaborative HST Treasury program (Davidson et al. 2001, 2003) provided detailed spectroscopic studies of η Car and selected structures of the Homunculus from Lyα to one micron. Zethson (2001) and Zethson et al. (2012) identified nearly two thousand narrow emission lines in the STIS moderate dispersion spectra of Weigelt B and D. While most lines originated from singly ionized species such as Fe++, narrow emission lines also were identified from Fe+++ and even Fe++++ (Zethson, 2001).

Several unanticipated discoveries resulted from the STIS long slit observations. A limiting factor of HST is that the solar panels must always be orientated towards the Sun. Hence the position angle of the long slit on the STIS has a bounded range that varies with time of the year. As our primary focus was on variations of η Car and secondarily on the Weigelt B, C and D, spectra of the emission blobs were obtained only when the slit orientation happened to include them or by additional spectra with specific offsets when necessary. Serendipity led to the detection of narrow, high-velocity, forbidden emission lines ultimately associated with the multiple shells created by the wind-wind interactions (Gull et al. 2009), an ionized bipolar structure associated with the Lesser Eruption of the 1890s (Ishibashi et al. 2003) and a very peculiar ionized metal region (Zethson et al., 2001).

Each long slit spectrum centered on η Car included weak forbidden line emission components at velocities ranging from -450 to +400 km s\(^{-1}\) even when Weigelt B, C or D was not intercepted by the slit position. These narrow components changed with position angle, date of observation and ionic species. Lines of [N II], [Fe III], [S III], [Ar III] and [Ne III] showed components from -450 to 0 km s\(^{-1}\) across the broad high state that disappeared during the low state. In contrast, lines of [Fe II] had velocity components from -450 to +400 km s\(^{-1}\) during the high state, but increased to include -400 to +400 km s\(^{-1}\) within the low state. An example is presented in Figure 3 of [Fe III] and [Fe II] extracted from the same spectrum centered on η Car. These fainter, red-shifted and blue-shifted narrow line emission structures ultimately proved to be spatially resolved structures caused by the interacting winds (Gull et al. 2009).

An earlier attempt to characterize the binary system using the STIS-derived velocity shifts of the He I absorption in the apparent P-Cygni line profiles led to the realization that the He I absorption originates from near the apex of the wind-wind interaction zone (Nielsen et al. 2007). The He I profiles and forbidden emission lines led to three-dimensional hydrodynamic modeling of the interacting winds that led to quantifying the properties

Figure 2 Left: Central 3’’ core of η Car and the Homunculus (HST/ACS F550M image). Right: Central 1’’ indicating η Car and the Weigelt condensations. The Weigelt condensations (labeled B, C and D) with intense narrow-line emission, additional condensations appear to form a ring around the central stellar component at a 0.25” radius. However, spectra of these condensations as seen by HST/STIS indicate scattered starlight and extended wind. This entire, complex region contributes to the spatially extended wind which HST/STIS resolves, but ground-based, visible spectroscopy cannot.
Figure 3 Left: Spectro-image of [Fe III] 4659Å recorded with HST/STIS. The central 0.1" region, including η Car, shows bright [Fe III] emission extending from -450 to +350 km s$^{-1}$. An arcuate loop of emission extends from -0.2" to +0.2" and from -450 to 0 km s$^{-1}$. By contrast, the [Fe II] 4815Å emission shows multiple arcs extending from -0.6" to +0.6" and from -450 to +400 km s$^{-1}$. The [Fe III] arcuate structure was replicated by 3-D modeling when the orbital pole of the model binary system was aligned to the axis of symmetry of the Homunculus, thus indicating a strong relationship between the binary system and the shape of the Homunculus (Madura 2010; Gull et al. 2009). Note the very bright [Fe II] emission at -40 km s$^{-1}$ which originates from slow moving material, including the Weigelt blobs, thought to have been ejected in the Lesser Eruption in the 1890s.

of the massive interacting winds (Madura 2010), determining that the orientation of the binary orbital axis is closely aligned to the axis of symmetry of the Homunculus (Madura et al. 2012) and more recently placing limits on how much the properties of the winds have changed over the past few cycles (Madura et al. 2013).

2.2 The Intermediate Ejecta

As with Alice examining Wonderland, the more that η Car and the Homunculus are observed, the results became curiouser and curiouser. The physical conditions of the Homunculus are quite varied. Mapping with the HST/STIS of the central four arc seconds in the Hβ spectral region revealed an internal, ionized bipolar shell, seen in multiple [Fe II] and other emission lines, that was ejected in the 1890s during the Lesser Eruption (Ishibashi et al. 2003). Likewise, mapping near the Hα spectral region revealed a very curious emission line region. Located about 2" north of η Car, the structure was first identified by [Sr II] at -110 and -100 km s$^{-1}$ velocities (Zethson et al. 2001). Subsequent HST/STIS spectra revealed many more forbidden emission lines, most notably of [Ti II] but no hydrogen, oxygen or carbon emission lines (Hartman et al. 2004). Analogous to the classical HII region, ionized by Lyman continuum, this region is excited by radiation that has been filtered by Fe$^+$ in the primary wind to energies less than about 8 eV. Hence hundreds of emission lines appear from many singly ionized metals including Ti$^+$, Sr$^+$, V$^+$, Sc$^+$, i.e. species not usually seen in HII regions for two reasons: the species are either ionized to higher states, or more likely the species have combined with carbon or oxygen to form molecules and eventually those molecules precipitate onto dust grains. The carbon and oxygen is so depleted that many metals are left in atomic and ionic states.

2.3 The Homunculus

The Homunculus, a dusty, bipolar shell expanding at 600 km s$^{-1}$, contains considerable material. The total mass of the Homunculus is difficult to quantify simply because of the huge range in velocities and the strange dust with high polarization and grey scattering properties. While estimates of the total mass have been derived based upon the infrared emission, the assumption of a gas to dust ratio being 100/1 is not supported. The dust grains formed from the Great Eruption were formed at high temperatures and have not cooled to the low temperatures of the ISM. They likely do not have ice mantles. Line of sight studies using the bright source, η Car, revealed a plethora of narrow absorption lines, mostly at -513 km s$^{-1}$ originating from a thin inner surface of the expanding shell (Gull et al 2005; Nielsen et al. 2005). Multiple additional absorption velocities were noted in singly-ionized species including the -146 km s$^{-1}$ component associable with the Little Homunculus. Most ranged at 10 to 20 km s$^{-1}$ in-
Figure 5 Top: 3-D model of H$_2$ as derived from VLT/XShooter spectroscopic mapping of the 2.12 µm emission line (Steffen et al. 2014, MNRAS July 8 issue). The bipolar lobes are distorted from the idealized hourglass shape: 1) a hole exists at the pole of each lobe, 2) a trench is seen on one side of each lobe, being point symmetrical from η Car, 3) two protrusions are located near the central region, but tilted relative to the dust skirt and to the previously inferred orbital plane of the binary, and 4) no H$_2$ is detected in the dusty skirt as noted by Smith (2006).

tervals between -585 to -380 km s$^{-1}$. Likely they are due to changes of primary wind velocity in line of sight from cycle to cycle since the Great Eruption, or evidence of long term changes in the primary wind velocity.

The -513 km s$^{-1}$ velocity component is seen in both ionic and molecular species. Approximately a thousand ionic absorptions were identified from Mg$^+$, Mn$^+$, Ti$^+$, V$^+$, Sc$^+$, Sr$^+$, Fe$^+$, etc. As many lines of these ions originate from levels above the ground state, we characterized the ion gas temperature to be 760°K. Over 800 H$_2$ absorption lines were observed coincident at the same velocity. In addition, combining HST/STIS and VLT/UVES spectra, we detected CH, OH and NH ground state absorptions but no CO. Quasithermal arguments would suggest that the molecular gas was cooler than 40°K. The H$_2$ absorptions are the result of electronic photo-excitation to upper levels with cascades down through many levels. Intriguingly the H$_2$ absorptions disappeared during the low state, confirming that the FUV radiation was cut off during the periastron event within the Homunculus. Deep to the interior Little Homunculus, multiple, very strong Ti$^+$ (13.8 eV ionization potential) absorptions appeared at -146 km s$^{-1}$ during the minimum, also confirming that the FUV was cut off within that smaller structure. Indeed η Car and the Homunculus is an astrophysical laboratory with time variable radiation input!

Observations with Herschel contain a number of molecular emission lines with multiple velocity components. Indeed molecular studies of the Homunculus are compounded by the huge velocity range from -600 to +600 km s$^{-1}$ that 1) requires very large velocity coverage and 2) high angular resolution meeting and exceeding the 0.1° angular resolution of HST. Strong clues are provided by the Herschel data (Gull et al., 2014, in prep) and promise much new, exciting results when and if ALMA time is granted.

An overall effort continues to characterize the Homunculus. Recently a complete spectroscopic mapping was accomplished with the VLT/XShooter and a 3-D model was derived using the H$_2$ 2.12 µm emission line (Steffen et al., 2014, MNRAS, July 8). Figure 5 depicts two views of the model as seen from Earth and as seen on the far side. Distortions from the bipolar structure indicate influence by the binary system at the time of the Great Eruption and possibly since the eruption.
3 The 2014.6 Periastron Event

Each of the last three periastrons has been followed with increasing interest as improved models of the binary system, especially of the interacting winds, are built in parallel with new observatories and instruments coming online. Indeed one major problem has been that ground-based telescopes and their instrumentation are upgraded/replaced often enough that no more than two periastron passages are observed by the same instrument. While the 1998.0 and 2009.1 passages were optimal for monitoring with night observations near the meridian, the 2003.5 and the upcoming 2014.6 passage occur while η Car is in the daytime sky. Hence, good monitoring from the ground is more achievable every alternate cycle, or eleven years.

Space observatories and their instrumentation tend to be used for longer intervals. The International Ultraviolet Explorer Observatory provided seventeen years of intermittent, proposal-dependent coverage, but occurred from 1978 to 1986, well before the 5.54-year period was discovered (Damineli 1996). Moreover, the 3" aperture and the 10” × 20” oval aperture did not provide separation of the stellar flux from the nebular-scattered and emitted fluxes. The optimally-matched imaging capabilities of the STIS to the HST proved ideal for the study of η Car and the Homunculus. Much more has been possible during the times when the STIS has been operational since 1998. However, the STIS experienced an electronic failure in early 2004 that extended to early 2009 but was repaired during the Servicing Mission 4 in May 2009. Discovery that the interacting winds could be traced has provided considerable new knowledge about how massive winds interact. The first spectra taken with HST/STIS after the Servicing Mission 4 was a demonstration mapping focused on measuring the extended wind interactions. One long slit spectrum from that mapping activity provided input to the graphic demonstrating the powers of imaging spectroscopy in Figure 6. This graphic is now used as an illustration of spatially-resolved spectroscopy and has appeared in a number of publications and textbooks.

The mapping activity demonstrated the ability to map with HST/STIS of structures 2" on the side and led to successful programs designed to map the extended wind structures over the current 5.54-year cycle in coordination with several X-ray observatories and multiple ground-based observatories. Currently we have followed the wind structures for the five years of the high (apastron) state. In a paper in preparation (Gull et al., 2014), slow, predictable changes are detected. Red-shifted shells in [Fe II] expand outward at 470 km s⁻¹ (Teodoro et al. 2013), Figure 7. Blue-shifted arcs move outward as similar speeds. Light house effects on the wind structures are traceable caused by the sweeping of FUV radiation as the secondary star moves in orbit carving a cavity in the massive primary (Gull et al., in prep).

η Car, through the monitoring of He I 6678Å narrow line emission, is predicted to enter the low state associated with the periastron passage on or about July 26 (Augusto Damineli, private communication). A few weeks later the already fluctuating X-ray flux, being monitored by SWIFT (Michael Corcoran) will disappear. The latest mapping with HST/STIS on June 7, 2014 indicated initial decline in total flux and shrinkage of various [Fe III] 4659Å structures along with increasing total flux and expansion of [Fe II] 4815Å structure. Ground-based spectroscopy, coordinated by Augusto Damineli, Mairan Teodoro and Noel Richard-

![Figure 6](image6.png)

**Figure 6** Graphic derived from the first set of observations with HST/STIS after STIS repair during the shuttle Servicing Mission 4 in May 2009. On the left is an HST/WFPC2 image with a projected STIS 0.1"-wide aperture projected on the central region offset from η Car. Extending outward from the image is an (arbitrary) color-encoded spectrum from 7000 to 7700Å. The vertical features labeled He, Ar, Fe, Ni are nebular emission from a portion of the interacting winds, the Little Homunculus and the Homunculus.

![Figure 7](image7.png)

**Figure 7** Mapping the winds of η Car recorded at intervals across the past five years. This is a red-shifted 40 km s⁻¹-wide velocity slice of [Fe II] 4815Å. The shells to the southeast of η Car are residual structures originating from the 2009.1, the 2003.5 and the 1998.0 wind-wind interactions. Teodoro et al (2013) found that these shells expand at 470 km s⁻¹, about ten percent higher than the independently measured primary wind velocity of 420 km s⁻¹ (Groh et al. 2012).
son, likewise see changes are beginning as predicted, especially in He I 4686Å. Ground-based photometry is continuously coordinated by Eduardo Fernando-Lajus.

Mapping visits with HST/STIS are scheduled for early August, and November of 2014 and mid-January, 2015 to measure the rapidly changing structures across periastron and recovery. The [Fe III] emission should be absent by early August when η Car is in the depths of the low state. In contrast, virtually all shells, excited by mid-UV from the primary star and collisions, will be visible in [Fe II]. By November, some [Fe III] emission from the innermost shells should be present and by January more shells will again be visible in [Fe III]. Ground-based spectroscopy will fill in the gaps between mappings showing how and when different velocity components again see the FUV radiation leading to doubly-ionized iron.

In parallel, X-ray spectroscopic observations are scheduled with CHANDRA, Suzaku, SWIFT and NuSTAR at critical times to increase understanding of the most energetic shock activity (Kenji Hamaguchi and Michael Corcoran). Critical to all of these observations are the 3-D hydrodynamical models that have been carefully developed by Madura et al. (2013). This paper provides predictions to be tested by the observations. The models are based upon the best estimates for the wind properties and predict at what phases changes should be occurring based primarily on the best estimate of the primay mass loss rate and potentially decreased mass loss rates. η Car has continued to gradually brighten, Hα flux has declined relative to continuum, and the 2009.1 X-ray minimum was half in time relative to the 1998.0 and 203.5 minima. These changes suggest that the primary wind mass loss rate is declining, but by how much? Madura’s models predict when changes should occur both in the decline and recovery, and based upon these predictions we should be able to constrain how much the winds have changed over the past three cycles.

However, η Car has always held back a few surprises. Will the anticipated changes take place as predicted? Do we know the physics well enough? Is the system stable or about to go through another major eruption? Stay tuned!

4 Acknowledgements

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A few years ago, a vote at an IAU meeting led to Pluto’s demotion as a planet. With a mass too small to clear its orbit of smaller objects, Pluto became a ‘dwarf planet.’ The international outcry was huge. Bring Back Pluto! Give Pluto a Chance! Despite the catchy slogans and many petitions, the IAU did not have a second vote. Pluto is still a dwarf planet.

For the public, this debate overshadows the many amazing features of Pluto. In its highly inclined orbit ($17^\circ$), the planet orbits the Sun exactly twice for every three orbits of Neptune. The Pluto-Charon system is a tidally locked binary with a separation of only $17 R_P$ (Pluto radii; $R_P \approx 1160$ km). Mutual occultations enable low resolution maps of light and dark areas on their surfaces.

Pluto-Charon is also a miniature planetary system (Figure 6). The four small moons have nearly circular, coplanar orbits with periods of 3.16 (Styx), 3.89 (Nix), 5.03 (Kerberos), and 5.98 (Hydra) times the period of the inner binary (Buie et al. 2006, Showalter et al. 2013). With typical masses of $10^{18} - 10^{20}$ g ($10^{-7} - 10^{-5}$ Pluto masses), the satellites are packed together as tightly as possible. Styx resides just outside the innermost stable orbit. Kerberos orbits within a small stable region between the orbits of Nix and Hydra (Youdin et al. 2012).

This architecture has some features similar to the more familiar Galilean satellites of Jupiter. With orbital separations of 6–27 Jupiter radii and masses of $10^{-5} - 10^{-4}$ Jupiter masses, the Galilean satellites are relatively more massive and have larger relative separations than the Pluto-Charon satellites. Collectively, the orbits of Pluto-Charon’s satellites and the Galilean satellites have small eccentricities and inclinations. Relative to the ecliptic plane, however, the Pluto-Charon orbital plane is very highly inclined, $\sim 120^\circ$, compared to the Galilean satellites, $\sim 3^\circ$.

Comparing the Pluto-Charon system to a set of circumbinary planets is also interesting (Figure 6). For each of the Kepler exoplanets, the larger orange (smaller red) dots plot the relative position of the primary (secondary) in units of the radius of the primary. The measured eccentricity and mass ratio of the binary set the position of the innermost stable orbit, marked as an asterisk. Beyond the asterisk, blue dots indicate the relative orbital distances of the exoplanets. For Kepler 47, a second exoplanet orbits beyond the outer boundary of the diagram.

Within this ensemble, there are clear similarities and differences in orbital architectures. Many systems have circumbinary planets/satellites orbiting close to the innermost orbit. With its small relative mass, Styx is closer to the innermost stable orbit than any of the exoplanets. The four moons of Pluto-Charon are also more tightly packed than any of the circumbinary planetary systems. The eccentric orbits of the central binary and the large relative
masses of the exoplanets prevent such close packing.

Scaling the Pluto-Charon system up to stellar masses suggests that a system of four Mars-mass to Earth-mass planets is stable around a pair of solar-type stars. It will be fun to see whether Kepler or TESS discover this kind of circumbinary planetary system.

Insights into Planet Formation: Planets form within circumstellar disks surrounding young stars. Various processes transform a disk of gas and dust into planets. Tiny (micron-sized) grains collide and merge into mm-sized to cm-sized objects. Continued agglomeration or some type of concentration mechanism yields 1–1000 km planetesimals. The planetesimals collide and grow into planets. Massive planets accrete gas to become gas giants.

Within this sequence, outcomes like Pluto or Charon are common and usually ignored. The more rare outcomes – Earths, Neptunes, and Jupiters – grab the headlines. However, Plutos are not simply stepping stones to these more massive planets. How Plutos form and evolve are central to the evolution of every planetary system.

In the rest of this Perspective, I will highlight a few of my favorite ways the Pluto-Charon system and other Pluto-mass objects inform our theories of planet formation.

Pluto Formation: Plutos probably form in one of two ways: agglomeration (coagulation) of much smaller (∼1–10 km) planetesimals or concentration of cm-sized pebbles into 100–1000 km protoplanets (Figure -5). In addition to problems associated with the ‘meter size barrier’ (Youdin & Kenyon 2013; Garaud et al 2013), coagulation is fairly slow: ∼10^4 yr at 1 AU, 1 Myr at 5 AU, and 100 Myr at 25 AU. Concentration avoids the meter size barrier and is much faster: ∼1–10 yr at 1 AU, 10–100 yr at 5 AU, and 100–1000 yr at 25 AU (Johansen et al 2007).

Aside from speed, the two paths may lead to very different kinds of planetary systems. Throughout coagulation, the largest protoplanets gravitationally stir small planetesimals. Small, rapidly moving planetesimals are harder to capture. Continued stirring slows accretion more and more. Eventually, protoplanets reach a limiting size which is somewhat larger than Pluto but much smaller than the Earth or the core of a giant planet (Inaba et al 2003, Kenyon & Bromley 2004). Although there may be ways around this bottleneck, they are relatively untested.

Concentration models provide a clearer path to the formation of Earths and larger planets. Once a Pluto forms, it starts to accrete pebbles on its own. In this mode of accretion, protoplanets tend to grow faster and faster until they run out of pebbles (Bromley & Kenyon 2011, Lambrechts & Johansen 2012). Protoplanetary disks have plenty of pebbles to produce Earth-mass planets.

Theory suggests a way to choose between these modes of planet formation (Choi et al 2002, Desch et al 2009, Guilbert-Lepoutre et al 2011). When growth is rapid, short-lived radioactive nuclei such as ^26 Al are incorporated into the planet. Heat from ^26 Al decay melts nearly all of the solids. The planet becomes differentiated, with a dense core and a less dense mantle. When growth is slow, ^26 Al decays before the solids agglomerate into a large planet. Although longer-lived nuclei can melt some of the planet, these planets are less differentiated. At 1 AU, coagulation and concentration are fast enough to enable ^26 Al melting in all massive, rocky protoplanets (Sanders & Scott 2012). Beyond 30 AU, however, coagulation is much too slow to trap ^26 Al in any Pluto-mass object. Thus, there should be clear differences in the internal structures of icy planets formed by coagulation or concentration.

In principle, observations of ice can distinguish between the fast and slow formation modes (Guilbert-Lepoutre et al 2011). In numerical calculations of the thermal structure of icy planets, the relative amounts of amorphous and crystalline ice near the surface of the planet depend on the thermal history. Large amounts of crystalline ice suggest high levels of radiogenic heating; negligible amounts suggest little radiogenic heating.
In practice, making a clear choice is not so simple. Other heating events can produce crystalline ice. High velocity collisions, formation close to the Sun, and other aspects of the internal structure contribute to crystallization. Still, new observations and better models of internal structure may provide ways to test predicted modes for planetesimal formation.

**Giant Impacts:** As in scenarios for the origin of the Moon, the standard model for the formation of Pluto-Charon involves a giant impact between two protoplanets (McKinnon 1984; Canup 2005, 2011). In this picture, a $\sim$ Charon-mass object collides with a $\sim$ Pluto-mass object. The geometry of the impact establishes the orbital plane of Pluto-Charon and any debris (Canup 2005, 2011).

Although there are many possible outcomes for a giant impact, it is simple to focus on two extreme outcomes (Canup 2005, 2011; Figure -4). In some grazing collisions, the impact produces a compact disk of material surrounding Pluto; material in the disk agglomerates into Charon and the satellites (Figure -4, left panels). In others, the proto-Charon survives the impact and forms an eccentric binary with Pluto. Small satellites grow out of the debris from the impact (Figure -4, right panels).

There are clear challenges with both models. In the ‘single survivor’ scenario, agglomeration processes must produce a single massive moon (Charon) and four smaller satellites. In a disk of particles with a fairly smooth surface density gradient, coagulation usually leads to a few larger objects which scatter away small leftovers (Chambers & Wetherill 1998; Chambers 2001; Kenyon & Bromley 2006). Forming a single large moon and several very small satellites in nearly circular orbits seems tricky. Even if this outcome is possible, it is hard for tidal forces to expand the orbits of the satellites from their initial compact state into a stable set of wider orbits (Peale et al. 2011).

Although the ‘binary survivor’ scenario avoids these issues, it introduces others (Kenyon & Bromley 2014). Once the binary establishes a stable eccentric orbit, tidal forces must expand the ring of particles into a disk with dimensions comparable to the scale of the current orbits of the satellites. As the disk expands, collisional damping must enable the growth of satellites from an ensemble of smaller particles. Getting the right balance of ring expansion and collisional damping is essential. Otherwise, satellites are either too close to or too far from the Pluto-Charon binary.

In a modification of this scenario, the satellites are simply the largest surviving fragments of the giant impact. Although this path avoids problems with growing the satellites from a disk of debris, the fragments must still find stable orbits within the expanding ring. Efficient collisional damping is a necessary aspect of this evolution.

Testing these possibilities requires detailed analytic studies and extensive numerical simulations. For the single survivor hypothesis, numerical simulations of satellite growth in a massive ring surrounding Pluto can place limits on likely outcomes as a function of initial conditions. If these outcomes seem favorable, it is important to find a stable mechanism which expands the orbits of small satellites from a compact configuration to the current configuration. Tidal forces acting on their own appear ruled out (Peale et al 2011). However, the agglomeration process that produces Charon and the small satellites might leave behind a tenuous disk of small particles surrounding the satellites. Dynamical friction between the small particles and the satellites tends to circularize satellite orbits. Numerical simulations are necessary to see if some combination of dynamical friction and tides can match the observed orbits of Pluto’s small satellites.

Right now, tests of the binary survivor hypothesis are encouraging (Kenyon & Bromley 2014): analytic estimates suggest tidal forces can expand the ring while collisional damping reduces the relative velocities of particles in the ring. Once damping overcomes tides, satellite formation is straightforward. As satellites grow, migration through the disk seems capable of placing satellites on reasonable orbits. Aside from yielding a rough match with the
bulk properties of the satellites, this model predicts a few smaller moons beyond the orbit of Hydra and perhaps some small particles of debris near the orbits of the current satellites.

**Circumbinary Exoplanets:** In the current paradigm, Kepler 16, Kepler 38, and other circumbinary exoplanets grow within a circumbinary disk. However, forming these planets so close to the central binary is a major challenge (Paardekooper et al. 2012). In these systems, the modest eccentricity of the binary induces an orbital eccentricity in solid material orbiting within the disk. Although collisional damping reduces the likely collision velocities among solid particles, the velocities are still too high to allow large grains or planetesimals to merge into larger objects. Thus, current theory focuses on models where planets form at much larger distances and then migrate close to the parent binary (Kley & Haghighipour 2014).

In the Pluto-Charon system, migration from large distances is not a viable option for the four small satellites (Canup 2005, 2011; Kenyon & Bromley 2014). Giant impacts rarely scatter debris far from the central object. Tidal forces cannot expand a ring of small particles much beyond the orbit of Hydra. Although Pluto-Charon could capture material from the Kuiper belt, the small efficiency precludes attracting enough material to make the small satellites. Thus, satellites form more or less in situ.

All in situ formation scenarios for the Pluto-Charon satellites appear to require efficient collisional damping within the impact debris. If one of these scenarios is correct, then it may be possible to construct numerical models for the in situ formation of circumbinary planets like Kepler 16 (see also Rafikov 2013). To begin, we need to transport our understanding of collisional damping in the gas-poor environments of disks generated from giant impacts to the Kuiper belt, a robust measure of the relative abundances of amorphous and crystalline ice might test formation theories for Pluto-Charon and the small satellites. Differences or gradients in composition among the satellites may yield interesting insights into the history of the system.

Despite its demotion, Pluto-Charon is an amazing binary system which now has a starring role in planet formation theory. After July 2015, New Horizons data will enable comprehensive tests of theories for coagulation, concentration, and giant impacts. Linking these results to observations of the growing population of circumbinary exoplanets will extend Pluto’s reach beyond the Solar System.

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From Gas to Stars in Energetic Environments: Dense Gas Clumps in the 30 Doradus Region Within the Large Magellanic Cloud

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We present parsec scale interferometric maps of HCN (1–0) and HCO⁺ (1–0) emission from dense gas in the star-forming region 30 Doradus, obtained using the Australia Telescope Compact Array. This extreme star-forming region, located in the Large Magellanic Cloud (LMC), is characterized by a very intense ultraviolet ionizing radiation field and sub-solar metallicity, both of which are expected to impact molecular cloud structure. We detect 13 bright, dense clumps within the 30 Doradus-10 giant molecular cloud. Some of the clumps are aligned along a filamentary structure with a characteristic spacing that is consistent with formation via the varicose fluid instability. Our analysis shows that the filament is gravitationally unstable and collapsing to form stars. There is a good correlation between HCO⁺ emission in the filament and signatures of recent star formation activity including H₂O masers and young stellar objects (YSOs). YSOs seem to continue along the same direction of the filament toward the massive compact star cluster R136 in the southwest. We present detailed comparisons of clump properties (masses, linewidths, sizes) in 30Dor-10 to those in other star forming regions of the LMC (N159, N113, N105, N44). Our analysis shows that the 30Dor-10 clumps have similar mass but wider linewidths and similar HCN/HCO⁺ (1-0) line ratios as clumps detected in other LMC star-forming regions. Our results suggest that the dense molecular gas clumps in the interior of 30Dor-10 are well-shielded against the intense ionizing field that is present in the 30Doradus region.

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The HH34 outflow as seen in [FeII]1.64μm by LBT-LUCI

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Dense atomic jets from young stars copiously emit in [FeII] IR lines, which can, therefore, be used to trace the immediate environments of embedded protostars. We want to investigate the morphology of the bright [FeII] 1.64μm line in the jet of the source HH34 IRS and compare it with the most commonly used optical tracer [SII]. We analyse a 1.64μm narrow-band filter image obtained with the Large Binocular Telescope (LBT) LUCI instrument, which covers
the HH34 jet and counterjet. A Point Spread Function (PSF) deconvolution algorithm was applied to enhance spatial resolution and make the IR image directly comparable to a [SII] HST image of the same source. The [FeII] emission is detected from both the jet, the (weak) counter-jet, and from the HH34-S and HH34-N bow shocks. The deconvolved image allows us to resolve jet knots close to about 1 arcsec from the central source. The morphology of the [FeII] emission is remarkably similar to that of the [SII] emission, and the relative positions of [FeII] and [SII] peaks are shifted according to proper motion measurements, which were previously derived from HST images. An analysis of the [FeII]/[SII] emission ratio shows that Fe gas abundance is much lower than the solar value with up to 90% of Fe depletion in the inner jet knots. This confirms previous findings on dusty jets, where shocks are not efficient enough to remove refractory species from grains.

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Deuterium chemistry of dense gas in the vicinity of low-mass and massive star forming regions

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The standard interstellar ratio of deuterium to hydrogen (D/H) atoms is \( \sim 1.5 \times 10^{-5} \). However, the deuterium fractionation is in fact found to be enhanced, to different degrees, in cold, dark cores, hot cores around massive star forming regions, lukewarm cores, and warm cores (hereafter, hot corinos) around low-mass star forming regions. In this paper, we investigate the overall differences in the deuterium chemistry between hot cores and hot corinos. We have modelled the chemistry of dense gas around low-mass and massive star forming regions using a gas-grain chemical model. We investigate the influence of varying the core density, the depletion efficiency of gaseous species on to dust grains, the collapse mode and the final mass of the protostar on the chemical evolution of star forming regions. We find that the deuterium chemistry is, in general, most sensitive to variations of the depletion efficiency on to grain surfaces, in agreement with observations. In addition, the results showed that the chemistry is more sensitive to changes in the final density of the collapsing core in hot cores than in hot corinos. Finally, we find that ratios of deuterated sulphur bearing species in dense gas around hot cores and corinos may be good evolutionary indicators in a similar way as their non deuterated counterparts.

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The extraordinary far-infrared variation of a protostar: Herschel/PACS observations of LRLL54361

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We report Herschel/PACS photometric observations at 70 μm and 160 μm of LRLL54361 - a suspected binary protostar that exhibits periodic (P=25.34 days) flux variations at shorter wavelengths (3.6 μm and 4.5 μm) thought to be due to pulsed accretion caused by binary motion. The PACS observations show unprecedented flux variation at these far-infrared wavelengths that are well correlated with the variations at shorter wavelengths. At 70 μm the object increases its flux by a factor of six while at 160 μm the change is about a factor of two, consistent with the wavelength dependence seen in the far-infrared spectra. The source is marginally resolved at 70 μm with varying FWHM. Deconvolved images of the sources show elongations exactly matching the outflow cavities traced by the scattered light observations. The spatial variations are anti-correlated with the flux variation indicating that a light echo is responsible for the changes in FWHM. The observed far-infrared flux variability indicates that the disk and envelope of this source is periodically heated by the accretion pulses of the central source, and suggests that such long wavelength variability in general may provide a reasonable proxy for accretion variations in protostars.

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A deep and wide-field view at the IC 2944 / 2948 complex in Centaurus

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We employed the ESO MPI wide-field camera and obtained deep images in the \( V \) and \( I \) pass-bands in the region of the IC 2944/2948 complex (\( l \sim 294^{\circ}; b \sim -1^{\circ} \)), and complemented them with literature and archival data. We used this material to derive the photometric, spectroscopic and kinematic properties of the brightest (\( V < 16 \)) stars in the region. The \( VI \) deep photometry on the other end, helped us to unravel the lower main sequence of a few, possibly physical, star groups in the area. Our analysis confirmed previous suggestions that the extinction toward this line of sight follows the normal law (\( R_V = 3.1 \)). We could recognize B-type stars spread in distance from a few hundred pc to at least 2 kpc. We found two young groups (age \( \sim 3 \) Myr) located respectively at about 2.3 and 3.2 kpc from the Sun. They are characterized by a significant variable extinction (\( E_{B-V} \) ranging from 0.28 to 0.45 mag), and host a significant pre-main sequence population. We computed the initial mass functions for these groups and obtained slopes \( \Gamma \) from \(-0.94 \) to \(-1.02 \) (\( c_{\Gamma} = 0.3 \)), in a scale where the classical Salpeter law is \(-1.35 \). We estimated the total mass of both main stellar groups in \( \sim1100 \) and \( \sim500 \) \( M_\odot \), respectively. Our kinematic analysis indicated that both groups of stars deviate from the standard rotation curve of the Milky Way, in line with literature results for this specific Galactic direction. Finally, along the same line of sight we identified a third group of early-type stars located at \( \sim8 \) kpc from the Sun. This group might be located in the far side of the Sagittarius-Carina spiral arm.

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New Galactic embedded clusters and candidates from a WISE Survey

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We carried out a search for new infrared star clusters, stellar groups and candidates using WISE images, which are
very sensitive to dust emission nebulae. We report the discovery of 437 embedded clusters and stellar groups that show a variety of structures, both in the stellar and nebular components. Pairs or small groupings of clusters are observed, suggesting multiple generations at the early formation stages. The resulting catalogue provides Galactic and equatorial coordinates, together with angular sizes for all objects. The nature of a representative test sub-sample of 14 clusters is investigated in detail by means of 2MASS photometry. The colour magnitude diagrams and radial density distributions characterize them as stellar clusters. The 437 new objects were found in the ranges $145^\circ \leq \ell \leq 290^\circ$ and $-25^\circ \leq b \leq 20^\circ$, and they appear to be a major object source for future studies of star cluster formation and their early evolution. WISE is a powerful tool to further probe for very young clusters throughout the disk.

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Radio Variability Survey of Very Low Luminosity Protostars

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Ten very low luminosity objects were observed multiple times in the 8.5 GHz continuum in search of protostellar magnetic activities. A radio outburst of IRAM 04191+1522 IRS was detected, and the variability timescale was about 20 days or shorter. The results of this survey and archival observations suggest that IRAM 04191+1522 IRS is in active states about half the time. Archival data show that L1014 IRS and L1148 IRS were detectable previously and suggest that at least 20%–30% of very low luminosity protostars are radio variables. Considering the variability timescale and flux level of IRAM 04191+1522 IRS and the previous detection of the circular polarization of L1014 IRS, the radio outbursts of these protostars are probably caused by magnetic flares. However, IRAM 04191+1522 IRS is too young and small to develop an internal convective dynamo. If the detected radio emission is indeed coming from magnetic flares, the discovery implies that the flares may be caused by the fossil magnetic fields of interstellar origin.

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Before the first supernova: combined effects of HII regions and winds on molecular clouds

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We model the combined effects of photoionization and momentum–driven winds from O–stars on molecular clouds spanning a parameter space of initial conditions. The dynamical effects of the winds are very modest. However, in the lower–mass clouds, they influence the morphologies of the HII regions by creating 10pc–scale central cavities. The inhomogeneous structures of the model GMCs make them highly permeable to photons, ionized gas and supernova ejecta, and the leaking of ionized gas in particular strongly affects their evolution, reducing the effectiveness of feedback. Nevertheless, feedback is able to expel large fractions of the mass of the lower escape–velocity clouds. Its impact on star formation is more modest, decreasing final star formation efficiencies by 10–20%, and the rate of change of the star formation efficiency per freefall time by about one third. However, the clouds still form stars substantially faster than observed GMCs.

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Modeling dust growth in protoplanetary disks: The breakthrough case

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Simple toy models are often not sufficient to cover the complexity of the dust coagulation process, and a number of numerical approaches are therefore used, among which integration of the Smoluchowski equation and various versions of Monte Carlo algorithm are the most popular. In this paper, we directly compare the Smoluchowski and Monte Carlo approaches and we find a general agreement for most of the coagulation problems. However, for the sweep-up growth driven by the “lucky” breakthrough mechanism, the methods exhibit very different resolution dependencies. With too few mass bins, the Smoluchowski algorithm tends to overestimate the growth rate and the probability of breakthrough. The Monte Carlo method is less resolution dependent in the growth timescale aspect but it tends to underestimate the breakthrough chance due to its limited dynamic mass range. We discuss the features and drawbacks of both the approaches, which may limit their astrophysical applications.

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Theory of fossil magnetic field

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Theory of fossil magnetic field is based on the observations, analytical estimations and numerical simulations of magnetic flux evolution during star formation in the magnetized cores of molecular clouds. Basic goals, main features of the theory and manifestations of MHD effects in young stellar objects are discussed.

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Constraining the Sub-AU-Scale Distribution of Hydrogen and Carbon Monoxide Gas around Young Stars with the Keck Interferometer

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We present Keck Interferometer observations of T Tauri and Herbig Ae/Be stars with a spatial resolution of a few milliarcseconds and a spectral resolution of $\sim$2000. Our observations span the $K$-band, and include the $Br\gamma$ transition of Hydrogen and the $v = 2-0$ and $v = 3-1$ transitions of carbon monoxide. For several targets we also present data from Keck/NIRSPEC that provide higher spectral resolution, but a seeing-limited spatial resolution, of the same spectral features. We analyze the $Br\gamma$ emission in the context of both disk and infall/outflow models, and conclude that the $Br\gamma$ emission traces gas at very small stellocentric radii, consistent with the magnetospheric scale. However some $Br\gamma$-emitting gas also seems to be located at radii of $>$0.1 AU, perhaps tracing the inner regions of magnetically launched outflows. CO emission is detected from several objects, and we generate disk models that reproduce both the KI and NIRSPEC data well. We infer the CO spatial distribution to be coincident with the distribution of continuum emission in most cases. Furthermore the $Br\gamma$ emission in these objects is roughly coincident with both the CO and continuum emission. We present potential explanations for the spatial coincidence of continuum, $Br\gamma$, and CO overtone emission, and explore the implications for the low occurrence rate of CO overtone emission in young stars. Finally, we provide
additional discussion of V1685 Cyg, which is unusual among our sample in showing large differences in emitting region size and spatial position as a function of wavelength.

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Search for Associations Containing Young stars (SACY). V. Is Multiplicity Universal?: Tight multiple systems

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Context: Dynamically undisrupted, young populations of stars are crucial to study the role of multiplicity in relation to star formation. Loose nearby associations provide us with a great sample of close (<150 pc) Pre-Main Sequence (PMS) stars across the very important age range (≈5-70 Myr) to conduct such research.

Aims: We characterize the short period multiplicity fraction of the SACY (Search for Associations Containing Young stars) accounting for any identifiable bias in our techniques and present the role of multiplicity fractions of the SACY sample in the context of star formation.

Methods: Using the cross-correlation technique we identified double-lined spectroscopic systems (SB2), in addition to this we computed Radial Velocity (RV) values for our subsample of SACY targets using several epochs of FEROS and UVES data. These values were used to revise the membership of each association then combined with archival data to determine significant RV variations across different data epochs characteristic of multiplicity; single-lined multiple systems (SB1).

Results: We identified 7 new multiple systems (SB1s: 5, SB2s: 2). We find no significant difference between the short period multiplicity fraction ($F_m$) of the SACY sample and that of nearby star forming regions (≈1-2 Myr) and the field ($F_m \leq 10\%$) both as a function of age and as a function of primary mass, $M_1$, in the ranges $P$ [1:200 day] and $M_2$ [0.08 $M_\odot$-$M_1$].

Conclusions: Our results are consistent with the picture of universal star formation, when compared to the field and nearby star forming regions (SFRs). We comment on the implications of the relationship between increasing multiplicity fraction with primary mass, within the close companion range, in relation to star formation.

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Modelling the sulphur chemistry evolution in Orion KL

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We study the sulphur chemistry evolution in the Orion KL along the gas and grain phases of the cloud. We investigate the processes that dominate the sulphur chemistry and to determine how physical and chemical parameters, such as the final star mass and the initial elemental abundances, influence the evolution of the hot core and of the surrounding outflows and shocked gas (the plateau). We independently modelled the chemistry evolution of both components using the time-dependent gas-grain model UCL\textsubscript{CHEM} and considering two different phase calculations. Phase I starts with the collapsing cloud and the depletion of atoms and molecules onto grain surfaces. Phase II starts when a central protostar is formed and the evaporation from grains takes place. We show how the gas density, the gas depletion efficiency, the initial sulphur abundance, the shocked gas temperature and the different chemical paths on the grains...
leading to different reservoirs of sulphur on the mantles affect sulphur-bearing molecules at different evolutionary stages. We also compare the predicted column densities with those inferred from observations of the species SO, SO$_2$, CS, OCS, H$_2$S and H$_2$CS. The models that reproduce the observations of the largest number of sulphur-bearing species are those with an initial sulphur abundance of 0.1 times the sulphur solar abundance and a density of at least $n_H = 5 \times 10^6$ cm$^{-3}$ in the shocked gas region. We conclude that most of the sulphur atoms were ionised during Phase I, consistent with an inhomogeneous and clumpy region where the UV interstellar radiation penetrates leading to sulphur ionisation. We also conclude that the main sulphur reservoir on the ice mantles was H$_2$S. In addition, we deduce that a chemical transition currently takes place in the shocked gas, where SO and SO$_2$ gas-phase formation reactions change from being dominated by O$_2$ to being dominated by OH.

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Probing the presence of planets in transition discs’ cavities via warps: the case of TW Hya

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We are entering the era in which observations of protoplanetary discs properties can indirectly probe the presence of massive planets or low mass stellar companions interacting with the disc. In particular, the detection of warped discs can provide important clues to the properties of the star-disc system. In this paper we show how observations of warped discs can be used to infer the dynamical properties of the systems. We concentrate on circumbinary discs, where the mass of the secondary can be planetary. First, we provide some simple relations that link the amplitude of the warp in the linear regime to the parameters of the system. Secondly, we apply our method to the case of TW Hya, a transition disc for which a warp has been proposed based on spectroscopic observations. Assuming values for the disc and stellar parameters from observations, we conclude that, in order for a warp induced by a planetary companion to be detectable, the planet mass should be large ($M_p \approx 10^{-14} M_J$) and the disc should be viscous ($\alpha \approx 0.15-0.25$). We also apply our model to LkCa 15 and T Cha, where a substellar companion has been detected within the central cavity of the transition discs.

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Dynamical structure of the inner 100 AU of the deeply embedded protostar IRAS 16293–2422

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A fundamental question about the early evolution of low-mass protostars is when circumstellar disks may form. High angular resolution observations of molecular transitions in the (sub)millimeter wavelength windows make it possible
to investigate the kinematics of the gas around newly-formed stars, for example to identify the presence of rotation and infall. IRAS 16293−2422 was observed with the extended Submillimeter Array (eSMA) resulting in subarcsecond resolution (0′.46 × 0′.29, i.e. ~55 × 35 AU) images of compact emission from the C$^{17}$O (3–2) and C$^{34}$S (7–6) transitions at 337 GHz (0.89 mm). To recover the more extended emission we have combined the eSMA data with SMA observations of the same molecules. The emission of C$^{17}$O (3–2) and C$^{34}$S (7–6) both show a velocity gradient oriented along a northeast-southwest direction with respect to the continuum marking the location of one of the components of the binary, IRAS16293A. Our combined eSMA and SMA observations show that the velocity field on the 50–400 AU scales is consistent with a rotating structure. It cannot be explained by simple Keplerian rotation around a single point mass but rather needs to take into account the enclosed envelope mass at the radii where the observed lines are excited. We suggest that IRAS 16293−2422 could be among the best candidates to observe a pseudo-disk with future high angular resolution observations.

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Modeling jet and outflow feedback during star cluster formation

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Powerful jets and outflows are launched from the protostellar disks around newborn stars. These outflows carry enough mass and momentum to transform the structure of their parent molecular cloud and to potentially control star formation itself. Despite their importance, we have not been able to fully quantify the impact of jets and outflows during the formation of a star cluster. The main problem lies in limited computing power. We would have to resolve the magnetic jet-launching mechanism close to the protostar and at the same time follow the evolution of a parsec-size cloud for a million years. Current computer power and codes fall orders of magnitude short of achieving this. In order to overcome this problem, we implement a subgrid-scale (SGS) model for launching jets and outflows, which demonstrably converges and reproduces the mass, linear and angular momentum transfer, and the speed of real jets, with ~1,000 times lower resolution than would be required without SGS model. We apply the new SGS model to turbulent, magnetized star cluster formation and show that jets and outflows (1) eject about 1/4 of their parent molecular clump in high-speed jets, quickly reaching distances of more than a parsec, (2) reduce the star formation rate by about a factor of two, and (3) lead to the formation of ~1.5 times as many stars compared to the no-outflow case. Most importantly, we find that jets and outflows reduce the average star mass by a factor of ~3 and may thus be essential for understanding the characteristic mass of the stellar initial mass function.

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Some like it cold: molecular emission and effective dust temperatures of dense cores in the Pipe Nebula

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Aims: The Pipe Nebula is characterized by a low star formation rate and is therefore an ideal environment to explore
how initial conditions, including core characteristics, affect star formation efficiencies.

**Methods:** In a continued study of the molecular core population of the Pipe Nebula, we present a molecular-line survey of 52 cores. Previous research has shown a variety of different chemical evolutionary stages among the cores. Using the Mopra radio telescope, we observed the ground rotational transitions of HCO\(^+\), H\(^{13}\)CO\(^+\), HCN, H\(^{13}\)CN, HNC, and N\(_2\)H\(^+\). These data are complemented with near-infrared extinction maps to constrain the column densities, effective dust temperatures derived from *Herschel* data, and NH\(_3\)-based gas kinetic temperatures.

**Results:** The target cores are located across the nebula, span visual extinctions between 5 and 67 mag, and effective dust temperatures (averaged along the lines of sight) between 13 and 19 K. The extinction-normalized integrated line intensities, a proxy for the abundance in constant excitation conditions of optically thin lines, vary within an order of magnitude for a given molecule. The effective dust temperatures and gas kinetic temperatures are correlated, but the effective dust temperatures are consistently higher than the gas kinetic temperatures. Combining the molecular line and temperature data, we find that N\(_2\)H\(^+\) is only detected toward the coldest and densest cores, while other lines show no correlation with these core properties.

**Conclusions:** Within this large sample, N\(_2\)H\(^+\) is the only species to exclusively trace the coldest and densest cores, in agreement with chemical considerations. In contrast, the common high-density tracers HCN and HNC are present in a majority of the cores, demonstrating the utility of these molecules for characterizing cores over a wide range of extinctions. The correlation between the effective dust temperatures and the gas kinetic temperatures suggests that the former are dominated by dust that is both dense and thermodynamically coupled to the dense gas traced by NH\(_3\). A direct use of the effective dust temperatures in a determination of dust column densities from dust emission measurements would, however, result in an underestimate of the dust column densities.

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**Reprocessing of Ices in Turbulent Protoplanetary Disks: Carbon and Nitrogen Chemistry**

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We study the influence of the turbulent transport on ice chemistry in protoplanetary disks, focusing on carbon and nitrogen bearing molecules. Chemical rate equations are solved with the diffusion term, mimicking the turbulent mixing in the vertical direction. Turbulence can bring ice-coated dust grains from the midplane to the warm irradiated disk surface, and the ice mantles are reprocessed by photoreactions, thermal desorption, and surface reactions. The upward transport decreases the abundance of methanol and ammonia ices at \(r < 30\) AU, because warm dust temperature prohibits their reformation on grain surfaces. This reprocessing could explain the smaller abundances of carbon and nitrogen bearing molecules in cometary coma than those in low-mass protostellar envelopes. We also show the effect of mixing on the synthesis of complex organic molecules (COMs) are two ways: (1) transport of ices from the midplane to the disk surface and (2) transport of atomic hydrogen from the surface to the midplane. The former enhances the COMs formation in the disk surface, while the latter suppresses it in the midplane. Then, when mixing is strong, COMs are predominantly formed in the disk surface, while their parent molecules are (re)formed in the midplane. This cycle expands the COMs distribution both vertically and radially outward compared with that in the non-turbulent model. We derive the timescale of the sink mechanism by which CO and N\(_2\) are converted to less volatile molecules to be depleted from the gas phase, and find that the vertical mixing suppresses this mechanism in the inner disks.

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**The protoplanetary disk of FT Tauri: multi-wavelength data analysis and modeling**

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Investigating the evolution of protoplanetary disks is crucial for our understanding of star and planet formation. Several theoretical and observational studies have been performed in the last decades to advance this knowledge. FT Tauri is a young star in the Taurus star forming region that was included in a number of spectroscopic and photometric surveys. We investigate the properties of the star, the circumstellar disk, and the accretion and ejection processes and propose a consistent gas and dust model also as a reference for future observational studies. We performed a multi-wavelength data analysis to derive the basic stellar and disk properties, as well as mass accretion/outflow rate from TNG-Dolores, WHT-Liris, NOT-Notcam, Keck-Nirspec, and Herschel-Pacs spectra. From the literature, we compiled a complete Spectral Energy Distribution. We then performed detailed disk modeling using the MCFOST and ProDiMo codes. Multi-wavelengths spectroscopic and photometric measurements were compared with the reddened predictions of the codes in order to constrain the disk properties. This object can serve as a benchmark for primordial disks with significant mass accretion rate, high gas content and typical size.

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Shadows and cavities in protoplanetary disks: HD163296, HD141569A, and HD150193A in polarized light

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The morphological evolution of dusty disks around young (few Myr-old) stars is pivotal to better understand planet formation. Since both dust grains and the global disk geometry evolve on short timescale, high-resolution imaging of a sample of objects may provide important hints towards such an evolution. We enlarge the sample of protoplanetary disks imaged in polarized light with high-resolution by observing the Herbig Ae/Be stars HD163296, HD141569A, and HD150193A. We integrate our data with previous datasets to paint a larger picture of their morphology. We report a weak detection of the disk around HD163296 in both H and Ks band. The disk is resolved as a broken ring structure with a significant surface brightness drop inward of 0.6 arcsec. No sign of extended polarized emission is detected from the disk around HD141569A and HD150193A. We propagate the absence of scattered light in the inner 0.6 arcsec around HD163296 and the non-detection of the disk around HD150193A may be due to similar geometric factors. Since these disks are known to be flat or only moderately flared, self-shadowing by the disk inner wall is the favored explanation. We show that the polarized brightness of a number of disks is indeed related to their flaring angle. Other scenarios (such as dust grain growth or interaction with icy molecules) are also discussed. On the other hand, the non-detection of HD141569A is consistent with previous datasets revealing the presence of a huge cavity in the dusty disk.

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The masses of young stars: CN as a probe of dynamical masses.

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We attempt to determine the masses of single or multiple young T Tauri and HAeBe stars from the rotation of their Keplerian disks. We used the IRAM PdBI interferometer to perform arcsecond resolution images of the CN N=2-1 transition with good spectral resolution. Integrated spectra from the 30-m radiotelescope show that CN is relatively unaffected by contamination from the molecular clouds. Our sample includes 12 sources, among which isolated stars like DM Tau and MWC 480 are used to demonstrate the method and its accuracy. We derive the dynamical mass by fitting a disk model to the emission, a process giving M/D the mass to distance ratio. We also compare the CN results with higher resolution CO data, that are however affected by contamination. All disks are found in nearly perfect Keplerian rotation. We determine accurate masses for 11 stars, in the mass range 0.5 to 1.9 $M_\odot$. The remaining one, DG Tau B, is a deeply embedded object for which CN emission partially arises from the outflow. With previous determination, this leads to 14 (single) stars with dynamical masses. Comparison with evolutionary tracks, in a distance independent modified HR diagram, show good overall agreement (with one exception, CW Tau), and indicate that measurement of effective temperatures are the limiting factor. The lack of low mass stars in the sample does not allow to distinguish between alternate tracks.

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Accretion and Diffusion Timescales in Sheets and Filaments

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A comparison of accretion and (turbulent) magnetic diffusion timescales for sheets and filaments demonstrates that dense star-forming clouds generally will – under realistic conditions – become supercritical due to mass accretion on timescales at least an order of magnitude shorter than ambipolar and/or turbulent diffusion timescales. Thus, ambipolar or turbulent diffusion – while present – is unlikely to control the formation of cores and stars.

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Two Extreme Young Objects in Barnard 1-b

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Two submm/mm sources in the Barnard 1b (B1-b) core, B1-bN and B1-bS, have been studied in dust continuum, H$^{13}$CO$^+$ J=1–0, CO J=2–1, $^{13}$CO J=2–1, and C$^{18}$O J=2–1. The spectral energy distributions of these sources from

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the mid-IR to 7 mm are characterized by very cold temperatures of \( T_{\text{dust}} < 20 \text{ K} \) and low bolometric luminosities of \( 0.15-0.31 \, L_\odot \). The internal luminosities of B1-bN and B1-bS are estimated to be \( <0.01-0.03 \, L_\odot \) and \( \sim 0.1-0.2 \, L_\odot \), respectively. Millimeter interferometric observations have shown that these sources have already formed central compact objects of \( \sim 100 \, \text{AU} \) sizes. Both B1-bN and B1-bS are driving the CO outflows with low characteristic velocities of \( \sim 2-4 \, \text{km/s} \). The fractional abundance of H\(^{13}\)CO\(^+\) at the positions of B1-bN and B1-bS is lower than the canonical value by a factor of 4–8. This implies that significant fraction of CO is depleted onto dust grains in dense gas surrounding these sources. The observed physical and chemical properties suggest that B1-bN and B1-bS are in the earlier evolutionary stage than most of the known Class 0 protostars. Especially, the properties of B1-bN agree with those of the first hydrostatic core predicted by the MHD simulations. The CO outflow was also detected in the mid-IR source located at \( \sim 15'' \) from B1-bS. Since the dust continuum emission was not detected in this source, the circumstellar material surrounding this source is less than \( 0.01 \, M_\odot \). It is likely that the envelope of this source was dissipated by the outflow from the protostar that is located to the southwest of B1-b.

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The evolution of accretion in young stellar objects: Strong accretors at 3–10 Myr
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While the rate of accretion onto T Tauri stars is predicted to decline with age, objects with strong accretion have been detected up to ages of 10 Myr. We analyze a sample of these old accretors identified by having a significant \( U \) band excess and infrared emission from a circumstellar disk. Objects were selected from the \( \sim 3 \) Myr \( \sigma \) Ori, 4–6 Myr Orion OB1b and 7–10 Myr Orion OB1a star forming associations. We use high resolution spectra from the Magellan Inamori Kiyocera Echelle to estimate the veiling of absorption lines and calculate extinction for our T Tauri sample. We also use observations, obtained with the Magellan Echellette and in a few cases the SWIFT Ultraviolet and Optical Telescope, to estimate the excess produced in the accretion shock, which is then fit with accretion shock models to estimate the accretion rate. We find that even objects as old as 10 Myr may have high accretion rates, up to \( \sim 10^{-8} \, M_\odot \, \text{yr}^{-1} \). These objects cannot be explained by viscous evolution models, which would deplete the disk in shorter timescales, unless the initial disk mass is very high, a situation which is unstable. We show that the infrared spectral energy distribution of one object, CVSO 206, does not reveal evidence of significant dust evolution, which would be expected during the 10 Myr lifetime. We compare this object to predictions from photoevaporation and planet formation models and suggest that neither of these processes have had a strong impact on the disk of CVSO 206.

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Lunar and Terrestrial Planet Formation in the Grand Tack Scenario
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We present conclusions from a large number of N-body simulations of the giant impact phase of terrestrial planet formation. We focus on new results obtained from the recently proposed Grand Tack model, which couples the gas-driven migration of giant planets to the accretion of the terrestrial planets. The giant impact phase follows the
The dynamics and star-forming potential of the massive Galactic centre cloud G0.253+0.016
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The massive infrared dark cloud G0.253+0.016 projected 45 pc from the Galactic centre contains ~ $10^5 M_\odot$ of dense gas whilst being mostly devoid of observed star-formation tracers. To scrutinise the physical properties, dynamics and structure of this cloud with reference to its star-forming potential, we have carried out a concerted SMA and IRAM 30m study of this cloud in dust continuum, CO isotopologues, shock tracing molecules, as well as H$_2$CO to trace the gas temperature. We detect and characterise a total of 36 dust cores within G0.253+0.016 at 1.3 mm and 1.37 mm, with masses between 25 and approximately 250 $M_\odot$, and find that the kinetic temperature of the gas traced by H$_2$CO ratios is >320 K on size-scales of ~0.15 pc. Analysis of the position-velocity diagrams of our observed lines show broad linewidths and strong shock emission in the south of the cloud, indicating that G0.253+0.016 is colliding with another cloud at $v_{LSR}$ ~ 70 km s$^{-1}$. We confirm via an analysis of the observed dynamics in the Central Molecular Zone that it is an elongated structure, orientated with Sgr B2 closer to the Sun than Sgr A*, however our results suggest that the actual geometry may be more complex than an elliptical ring. We find that the column density Probability Distribution Function (PDF) of G0.253+0.016 is log-normal with no discernible power-law tail, consistent with little star formation, and that its width can be explained in the framework of theory predicting the density structure of clouds created by supersonic, magnetised turbulence. We also present the delta-variance spectrum of this region, and show it is consistent with that expected for clouds with no star formation. Using G0.253+0.016 as a test-bed of the conditions required for star formation in a different physical environment to that of nearby clouds, we also conclude that there is not one column density threshold for star formation, but instead this value is dependant on the local physical conditions. (Abbrev.)

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New BVIc Photometry of Low-Mass Pleiades Stars: Exploring the Effects of Rotation on Broadband Colors
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We present new BVIc photometry for 350 Pleiades proper-motion members with $9 < V < 17$. Importantly, our new...
catalog includes a large number of K and early-M type stars, roughly doubling the number of low-mass stars with well calibrated Johnson/Cousins photometry in this benchmark cluster. We combine our new photometry with existing photometry from the literature to define a purely empirical isochrone at Pleiades age ($\approx 100$ Myr) extending from $V = 9$ to 17. We use the empirical isochrone to identify 48 new probable binaries and 14 likely non-members. The photometrically identified single stars are compared against their expected positions in the color-magnitude diagram (CMD). At 100 Myr, the mid K and early M stars are predicted to lie above the zero-age main sequence (ZAMS) having not yet reached the ZAMS. We find in the B-V vs. V CMD that mid K and early M dwarfs are instead displaced below (or bluward of) the ZAMS. Using the stars’ previously reported rotation periods, we find a highly statistically significant correlation between rotation period and CMD displacement, in the sense that the more rapidly rotating stars have the largest displacements in the B-V CMD.

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Herschel Evidence for Disk Flattening or Gas Depletion in Transitional Disks

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Transitional disks are protoplanetary disks characterized by reduced near- and mid-infrared emission, with respect to full disks. This characteristic spectral energy distribution indicates the presence of an optically thin inner cavity within the dust disk believed to mark the disappearance of the primordial massive disk. We present new Herschel Space Observatory PACS spectra of [O I] 63.18 $\mu$m for 21 transitional disks. Our survey complements the larger Herschel GASPS program (“Gas in Protoplanetary Systems”) by quadrupling the number of transitional disks observed with PACS in this wavelength. [O I] 63.18 $\mu$m traces material in the outer regions of the disk, beyond the inner cavity of most transitional disks. We find that transitional disks have [O I] 63.18 $\mu$m line luminosities 2 times fainter than their full disk counterparts. We self-consistently determine various stellar properties (e.g., bolometric luminosity, FUV excess, etc.) and disk properties (e.g., disk dust mass, etc.) that could influence the [O I] 63.18 $\mu$m line luminosity, and we find no correlations that can explain the lower [O I] 63.18 $\mu$m line luminosities in transitional disks. Using a grid of thermo-chemical protoplanetary disk models, we conclude that either transitional disks are less flared than full disks or they possess lower gas-to-dust ratios due to a depletion of gas mass. This result suggests that transitional disks are more evolved than their full disk counterparts, possibly even at large radii.

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Debris disc formation induced by planetary growth
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Several hundred stars older than 10 million years have been observed to have infrared excesses. These observations are
explained by dust grains formed by the collisional fragmentation of hidden planetesimals. Such dusty planetesimal discs are known as debris discs. In a dynamically cold planetesimal disc, collisional coagulation of planetesimals produces planetary embryos which then stir the surrounding leftover planetesimals. Thus, the collisional fragmentation of planetesimals that results from planet formation forms a debris disc. We aim to determine the properties of the underlying planetesimals in debris discs by numerically modelling the coagulation and fragmentation of planetesimal populations. The brightness and temporal evolution of debris discs depend on the radial distribution of planetesimal discs, the location of their inner and outer edges, their total mass, and the size of planetesimals in the disc. We find that a radially narrow planetesimal disc is most likely to result in a debris disc that can explain the trend of observed infrared excesses of debris discs around G-type stars, for which planet formation occurs only before 100 million years. Early debris disc formation is induced by planet formation, while the later evolution is explained by the collisional decay of leftover planetesimals around planets that have already formed. Planetesimal discs with underlying planetesimals of radii $\sim 100$ km at $\approx 30$ AU most readily explain the Spitzer Space Telescope 24 and 70 $\mu$m fluxes from debris discs around G-type stars.

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Toward Complete Statistics of Massive Binary Stars: Penultimate Results from the Cygnus OB2 Radial Velocity Survey

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We analyze orbital solutions for 48 massive multiple-star systems in the Cygnus OB2 Association, 23 of which are newly presented here, to find that the observed distribution of orbital periods is approximately uniform in log $P$ for $P < 45$ d, but it is not scale-free. Inflections in the cumulative distribution near 6 d, 14 d, and 45 d, suggest key physical scales of $\sim 0.2$, $\sim 0.4$, and $\sim 1$ AU where yet-to-be-identified phenomena create distinct features. No single power law provides a statistically compelling prescription, but if features are ignored, a power law with exponent $\beta = -0.22$ provides a crude approximation over $P = 1.4 - 2000$ d, as does a piece-wise linear function with a break near 45 d. The cumulative period distribution flattens at $P > 45$ d, even after correction for completeness, indicating either a lower binary fraction or a shift toward low-mass companions. A high degree of similarity (91% likelihood) between the Cyg OB2 period distribution and that of other surveys suggests that the binary properties at $P < 25$ d are determined by local physics of disk/clump fragmentation and are relatively insensitive to environmental and evolutionary factors. Fully 30% of the unbiased parent sample is a binary with period $P < 45$ d. Completeness corrections imply a binary fraction near 55% for $P < 5000$ d. The observed distribution of mass ratios $0.2 < q < 1$ is consistent with uniform, while the observed distribution of eccentricities $0.1 < e < 0.6$ is consistent with uniform plus an excess of $e \sim 0$ systems. We identify six stars, all supergiants, that exhibit aperiodic velocity variations of $\sim 30$ km s$^{-1}$ attributed to atmospheric fluctuations.

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A dearth of small particles in debris disks: An energy-constrained smallest fragment size
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A prescription for the fragment size distribution resulting from dust grain collisions is essential when modelling a range of astrophysical systems, such as debris disks and planetary rings. While the slope of the fragment size distribution and the size of the largest fragment are well known, the behaviour of the distribution at the small size end is theoretically and experimentally poorly understood. This leads debris disk codes to generally assume a limit equal to, or below, the radiation blow-out size. We use energy conservation to analytically derive a lower boundary of the fragment size distribution for a range of collider mass ratios. Focussing on collisions between equal-sized bodies, we apply the method to debris disks. For a given collider mass, the size of the smallest fragments is found to depend on collision velocity, material parameters, and the size of the largest fragment. We provide a physically motivated recipe for the calculation of the smallest fragment, which can be easily implemented in codes for modelling collisional systems. For plausible parameters, our results are consistent with the observed predominance of grains much larger than the blow-out size in Fomalhaut’s main belt and in the Herschel cold debris disks.

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Investigation of the stellar content in the western part of the Carina nebula
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We obtained deep \textit{UBVRI} H\textalpha{} photometric data of the field situated to the west of the main Carina nebula and centered on WR 22. Medium-resolution optical spectroscopy of a subsample of X-ray selected objects along with archival data sets from Chandra, XMMNewton and 2MASS surveys were used for the present study. Different sets of color-color and color-magnitude diagrams are used to determine reddening for the region and to identify young stellar objects (YSOs) and estimate their age and mass. Our spectroscopic results indicate that the majority of the X-ray sources are late spectral type stars. The region shows a large amount of differential reddening with minimum and maximum values of $E(B−V)$ as 0.25 and 1.1 mag, respectively. Our analysis reveals that the total-to-selective absorption ratio $R_V$ is $\sim 3.7 \pm 0.1$, suggesting an abnormal grain size in the observed region. We identified 467 YSOs and studied their characteristics. The ages and masses of the 241 optically identified YSOs range from $\sim$0.1 to 10 Myr and $\sim$0.3 to 4.8 $M_\odot$, respectively. However, the majority of them are younger than 1 Myr and have masses below 2 $M_\odot$. The high mass star WR 22 does not seem to have contributed to the formation of YSOs in the CrW region. The initial mass function slope, $\Gamma$, in this region is found to be $-1.13 \pm 0.20$ in the mass range of $0.5 < M/M_\odot < 4.8$. The $K$-band luminosity function slope ($\alpha$) is also estimated as 0.31 $\pm$ 0.01. We also performed minimum spanning tree analysis of the YSOs in this region, which reveals that there are at least ten YSO cores associated with the molecular cloud, and that leads to an average core radius of 0.43 pc and a median branch length of 0.28 pc.

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A search for flares and mass ejections on young late-type stars in the open cluster Blanco-1
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We present a search for stellar activity (flares and mass ejections) in a sample of 28 stars in the young open cluster Blanco-1. We use optical spectra obtained with ESO’s VIMOS multi-object spectrograph installed on the VLT. From the total observing time of $\sim 5$ hours, we find four H$\alpha$ flares but no distinct indication of coronal mass ejections (CMEs) on the investigated dK-dM stars. Two flares show “dips” in their light-curves right before their impulsive phases which are similar to previous discoveries in photometric light-curves of active dMe stars. We estimate an upper limit of $<4$ CMEs per day per star and discuss this result with respect to a semi-empirical estimation of the CME rate of main-sequence stars. We find that we should have detected at least one CME per star with a mass of $1-15 \times 10^{16}$ g depending on the star’s X-ray luminosity, but the estimated H$\alpha$ fluxes associated with these masses are below the detection limit of our observations. We conclude that the parameter which mainly influences the detection of stellar CMEs using the method of Doppler-shifted emission caused by moving plasma is not the spectral resolution or velocity but the flux or mass of the CME.

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Sejong Open Cluster Survey (SOS). III. The Young Open Cluster NGC 1893 in the H II Region W8

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We present a $UBVI$ and H$\alpha$ photometric study of the young open cluster NGC 1893 in the H II region W8 (IC 410 or Sh 2-236). A total of 65 early-type members are selected from photometric diagrams. A mean reddening of the stars is $<E(B-V)> = 0.563 \pm 0.083$ mag. The published photometric data in the near- and mid-infrared passbands are used to test the reddening law toward the cluster, and we confirm that the reddening law is normal ($R_V = 3.1$). Zero-age main sequence fitting gives a distance modulus of $V_0 - M_V = 12.7 \pm 0.2$ mag, equivalent to $3.5 \pm 0.3$ kpc. From H$\alpha$ photometry 125 H$\alpha$ emission stars and candidates are identified as pre-main sequence (PMS). The lists of young stellar objects and X-ray sources published by previous studies allow us to select a large number of PMS members down to 1 $M_\odot$. Isochrone fitting in the Hertzsprung-Russell diagram gives a turn-off age of 1.5 Myr and the median age of 1.9 Myr from the PMS members with a spread of 5 Myr. We derive the initial mass function (IMF) for stars with mass larger than 1 $M_\odot$. The slope of the IMF ($\Gamma = -1.3 \pm 0.1$) is well consistent with the Salpeter/Kroupa IMF. A total mass of the cluster appears to be in excess of 1,300 $M_\odot$. Finally, we estimate the mass accretion rate of 82 PMS members in the mass range of 0.6 $M_\odot$ to 5 $M_\odot$.

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VLA observations of ammonia in high-mass star formation regions

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We present a search for stellar activity (flares and mass ejections) in a sample of 28 stars in the young open cluster Blanco-1. We use optical spectra obtained with ESO’s VIMOS multi-object spectrograph installed on the VLT. From the total observing time of $\sim 5$ hours, we find four H$\alpha$ flares but no distinct indication of coronal mass ejections (CMEs) on the investigated dK-dM stars. Two flares show “dips” in their light-curves right before their impulsive phases which are similar to previous discoveries in photometric light-curves of active dMe stars. We estimate an upper limit of $<4$ CMEs per day per star and discuss this result with respect to a semi-empirical estimation of the CME rate of main-sequence stars. We find that we should have detected at least one CME per star with a mass of $1-15 \times 10^{16}$ g depending on the star’s X-ray luminosity, but the estimated H$\alpha$ fluxes associated with these masses are below the detection limit of our observations. We conclude that the parameter which mainly influences the detection of stellar CMEs using the method of Doppler-shifted emission caused by moving plasma is not the spectral resolution or velocity but the flux or mass of the CME.

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We present a $UBVI$ and H$\alpha$ photometric study of the young open cluster NGC 1893 in the H II region W8 (IC 410 or Sh 2-236). A total of 65 early-type members are selected from photometric diagrams. A mean reddening of the stars is $<E(B-V)> = 0.563 \pm 0.083$ mag. The published photometric data in the near- and mid-infrared passbands are used to test the reddening law toward the cluster, and we confirm that the reddening law is normal ($R_V = 3.1$). Zero-age main sequence fitting gives a distance modulus of $V_0 - M_V = 12.7 \pm 0.2$ mag, equivalent to $3.5 \pm 0.3$ kpc. From H$\alpha$ photometry 125 H$\alpha$ emission stars and candidates are identified as pre-main sequence (PMS). The lists of young stellar objects and X-ray sources published by previous studies allow us to select a large number of PMS members down to 1 $M_\odot$. Isochrone fitting in the Hertzsprung-Russell diagram gives a turn-off age of 1.5 Myr and the median age of 1.9 Myr from the PMS members with a spread of 5 Myr. We derive the initial mass function (IMF) for stars with mass larger than 1 $M_\odot$. The slope of the IMF ($\Gamma = -1.3 \pm 0.1$) is well consistent with the Salpeter/Kroupa IMF. A total mass of the cluster appears to be in excess of 1,300 $M_\odot$. Finally, we estimate the mass accretion rate of 82 PMS members in the mass range of 0.6 $M_\odot$ to 5 $M_\odot$.

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VLA observations of ammonia in high-mass star formation regions

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We report systematic mapping observations of the NH$_3$ (1,1) and (2,2) inversion lines towards 62 high-mass star-forming regions using VLA in its D and DnC array configurations. The VLA images cover a spatial dynamic range from 40$''$ to 3$''$, allowing us to trace gas kinematics from $\sim$1 pc scales to $\lesssim$0.1 pc scales. Based on the NH$_3$ morphology and the infrared nebulosity on 1 pc scales, we categorize three sub-classes in the sample: filaments, hot cores, and NH$_3$ dispersed sources. The ubiquitous gas filaments found on 1 pc scales have a typical width of $\sim$0.1 pc and often contain regularly spaced fragments along the major axis. The spacing of the fragments and the column densities are consistent with the turbulent supported fragmentation of cylinders. Several sources show multiple filaments that converge toward a center, where the velocity field in the filaments is consistent with gas flows. We derive rotational temperature maps for the entire sample. For the three hot core sources, we find a projected radial temperature distribution that is best fitted by power-law indices from −0.18 to −0.35. We identify 174 velocity-coherent $\sim$0.1 pc scale dense cores from the entire sample. The mean physical properties for these cores are 1.1 km s$^{-1}$ in intrinsic linewidth, 18 K in NH$_3$ rotational temperature, 2.3\times10^{15}$ cm$^{-2}$ in NH$_3$ gas column density, and 67 $M_\odot$ in molecular mass. The dense cores identified from the filamentary sources are closer to be virialized. Dense cores in the other two categories of sources appear to be dynamically unstable.

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Location and sizes of forsterite grains in protoplanetary disks - Interpretation from the Herschel DIGIT programme

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The spectra of protoplanetary disks contain mid- and far- infrared emission features produced by forsterite dust grains. The spectral features contain information about the forsterite temperature, chemical composition and grain size. We aim to characterize how the 23 and 69 $\mu$m features can be used to constrain the physical locations of forsterite in disks. We check for consistency between two independent forsterite temperature measurements: the $I_{23}/I_{69}$ feature strength ratio and the shape of the 69 $\mu$m band. We perform radiative transfer modeling to study the effect of disk properties to the forsterite spectral features. Temperature dependent forsterite opacities are considered in self consistent models to compute forsterite emission from protoplanetary disks. Modeling grids are presented to study the effects of grain size, disk gaps, radial mixing and optical depth to the forsterite features. Independent temperature estimates derived from the $I_{23}/I_{69}$ feature strength ratio and the 69 $\mu$m band shape are not consistent for HD 141569 and Oph IRS 48. A case study of the disk of HD 141569 shows two solutions to fit the forsterite spectrum. A model with $T \sim 40$ K, iron rich ($\sim 0 - 1\%$ Fe) and 1 $\mu$m forsterite grains, and a model with warmer ($T \sim 100$ K), iron free, and larger (10 $\mu$m) grains. We find that for disks with low upper limits of the 69 $\mu$m feature (most notably in flat, self-shadowed disks), the forsterite must be hot, and thus close to the star. We find no correlation between disk gaps and the presence or absence of forsterite features. We argue that the 69 $\mu$m feature of the evolved transitional disks HD 141569 and Oph IRS 48 is most likely a tracer of larger (i.e. & 10 $\mu$m) forsterite grains.
On the gas content of transitional disks: a VLT/X-Shooter study of accretion and winds

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Context: Transitional disks are thought to be a late evolutionary stage of protoplanetary disks whose inner regions have been depleted of dust. The mechanism responsible for this depletion is still under debate. To constrain the various models it is mandatory to have a good understanding of the properties of the gas content in the inner part of the disk.

Aims: Using X-Shooter broad band - UV to NIR - medium resolution spectroscopy we derive the stellar, accretion, and wind properties of a sample of 22 transitional disks. The analysis of these properties allows us to put strong constraints on the gas content in a region very close to the star (< 0.2 AU) which is not accessible with any other observational technique.

Methods: We fit the spectra with a self-consistent procedure to derive simultaneously spectral type, extinction, and accretion properties of the targets. From the continuum excess at near-infrared wavelength we distinguish whether our targets have dust free inner holes. Analyzing forbidden emission lines we derive the wind properties of the targets. We then compare our findings to results for classical TTauri stars.

Results: The accretion rates and wind properties of 80% of the transitional disks in our sample, which is strongly biased towards strongly accreting objects, are comparable to those of classical TTauri stars. Thus, there are (at least) some transitional disks with accretion properties compatible with those of classical TTauri stars, irrespective of the size of the dust inner hole. Only in 2 cases the mass accretion rates are much lower, while the wind properties remain similar. We do not see any strong trend of the mass accretion rates with the size of the dust depleted cavity, nor with the presence of a dusty optically thick disk very close to the star. These results suggest that, close to the central star, there is a gas rich inner disk with density similar to that of classical TTauri stars disks.

Conclusions: The sample analyzed here suggests that, at least for some objects, the process responsible of the inner disk clearing should allow for a transfer of gas from the outer disk to the inner region. This should proceed at a rate that does not depend on the physical mechanism producing the gap seen in the dust emission and results in a gas density in the inner disk similar to that of unperturbed disks around stars of similar mass.

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The First Very Long Baseline Interferometry Image of 44 GHz Methanol Maser with the KVN and VERA Array (KaVA)

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We have carried out the first very long baseline interferometry (VLBI) imaging of 44 GHz class I methanol maser (\(7_0-6_1A^+\)) associated with a millimeter core MM2 in a massive star-forming region IRAS 18151−1208 with KaVA (KVN and VERA Array), which is a newly combined array of KVN (Korea VLBI Network) and VERA (VLBI Exploration of Radio Astrometry). We have succeeded in imaging compact maser features with a synthesized beam size of 2.7 milliarcseconds \(\times\) 1.5 milliarcseconds (mas). These features are detected at a limited number of baselines within the length of shorter than \(\approx 650\) km corresponding to 100 M\(\lambda\) in the uv-coverage. The central velocity and the velocity width of the 44 GHz methanol maser are consistent with those of the quiescent gas rather than the outflow traced by the SiO thermal line. The minimum component size among the maser features is \(\sim 5\) mas \(\times\) 2 mas, which corresponds to the linear size of about 15 AU \(\times\) 6 AU assuming a distance of 3 kpc. The brightness temperatures of these features range from \(\sim 3.5 \times 10^8\) to \(1.0 \times 10^{10}\) K, which are higher than estimated lower limit from a previous Very Large Array observation with the highest spatial resolution of \(\sim 50\) mas. The 44 GHz class I methanol maser in IRAS 18151−1208 is found to be associated with the MM2 core, which is thought to be less evolved than another millimeter core MM1 associated with the 6.7 GHz class II methanol maser.

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Stellar parameters and accretion rate of the transition disk star HD 142527 from X-Shooter

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HD 142527 is a young pre-main sequence star with properties indicative of the presence of a giant planet or/and a low-mass stellar companion. We have analyzed an X-Shooter/Very Large Telescope spectrum to provide accurate
stellar parameters and accretion rate. The analysis of the spectrum, together with constraints provided by the SED fitting, the distance to the star (140 ± 20 pc) and the use of evolutionary tracks and isochrones, lead to the following set of parameters \( T_{\text{eff}} = 6550 \pm 100 \text{ K}, \log g = 3.75 \pm 0.10, \frac{L_*}{L_\odot} = 16.3 \pm 4.5, \frac{M_*}{M_\odot} = 2.0 \pm 0.3 \) and an age of 5.0 ± 1.5 Myr. This stellar age provides further constrains to the mass of the possible companion estimated by Biller et al. (2012), being in-between 0.20 and 0.35 \( M_\odot \). Stellar accretion rates obtained from UV Balmer excess modelling, optical photospheric line veiling, and from the correlations with several emission lines spanning from the UV to the near-IR, are consistent to each other. The mean value from all previous tracers is \( 2 (\pm 1) \times 10^{-7} \text{ M}_\odot \text{ yr}^{-1} \), which is within the upper limit gas flow rate from the outer to the inner disk recently provided by Cassasus et al. (2013). This suggests that almost all gas transferred between both components of the disk is not trapped by the possible planet(s) in-between but fall onto the central star, although it is discussed how the gap flow rate could be larger than previously suggested. In addition, we provide evidence showing that the stellar accretion rate of HD 142527 has increased by a factor \( \sim 7 \) on a timescale of 2-5 years.

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A probable pre-main sequence chemically peculiar star in the open cluster Stock 16

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We used the Ultraviolet and Visual Echelle Spectrograph of the ESO-Very Large Telescope to obtain a high resolution and high signal-to-noise ratio spectrum of Stock 16-12, an early-type star which previous \( \Delta a \) photometric observations suggest being a chemically peculiar (CP) star. We used spectral synthesis to perform a detailed abundance analysis obtaining an effective temperature of 8400 ± 400 K, a surface gravity of 4.1 ± 0.4, a microturbulence velocity of 3.4 ± 0.7 km s\(^{-1}\), and a projected rotational velocity of 68 ± 4 km s\(^{-1}\). We provide photometric and spectroscopic evidence showing the star is most likely a member of the young Stock 16 open cluster (age 3–8 Myr). The probable cluster membership, the star’s position in the Hertzsprung-Russell diagram, and the found infrared excess strongly suggest the star is still in the pre-main-sequence (PMS) phase. We used PMS evolutionary tracks to determine the stellar mass, which ranges between 1.95 and 2.3 \( M_\odot \), depending upon the adopted spectroscopic or photometric data results. Similarly, we obtained a stellar age ranging between 4 and 6 Myr, in agreement with that of the cluster. Because the star’s chemical abundance pattern resembles well that known of main sequence CP metallic line (Am) stars, the object sets important constraints to the diffusion theory. Additional spectroscopic and spectropolarimetric data allowed us to conclude that the object is probably a single non-magnetic star.

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X-Shooter spectroscopy of young stellar objects: V - Slow winds in T Tauri stars

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Disks around T Tauri stars are known to lose mass, as best shown by the profiles of forbidden emission lines of low ionization species. At least two separate kinematic components have been identified, one characterised by velocity shifts of tens to hundreds km s$^{-1}$ (HVC) and one with much lower velocity of few km s$^{-1}$ (LVC). The HVC are convincingly associated to the emission of jets, but the origin of the LVC is still unknown. In this paper we analyze the forbidden line spectrum of a sample of 44 mostly low mass young stars in Lupus and σ-Ori observed with the X-Shooter ESO spectrometer. We detect forbidden line emission of [OI], [OII], [SII], [NI], and [NII], and characterize the line profiles as LVC, blue-shifted HVC and red-shifted HVC. We focus our study on the LVC. We show that there is a good correlation between line luminosity and both $L_{\text{star}}$ and the accretion luminosity (or the mass-accretion rate) over a large interval of values ($L_{\text{star}} \sim 10^{-2} - 10^{-1} L_\odot$; $L_{\text{acc}} \sim 10^{-5} - 10^{-1} L_\odot$; $M_{\text{acc}} \sim 10^{-11} - 10^{-7} M_\odot$ yr$^{-1}$). The lines show the presence of a slow wind ($V_{\text{peak}} < 20$ km s$^{-1}$), dense ($n_H > 10^8$ cm$^{-3}$), warm ($T \sim 5000$–$10000$ K), mostly neutral. We estimate the mass of the emitting gas and provide a value for the maximum volume it occupies. Both quantities increase steeply with the stellar mass, from $\sim 3 \times 10^{-12}$ $M_\odot$ and $\sim 0.01$ AU$^3$ for $M_{\text{star}} \sim 0.1$ $M_\odot$, to $\sim 3 \times 10^{-10}$ $M_\odot$ and $\sim 1$ AU$^3$ for $M_{\text{star}} \sim 1$ $M_\odot$, respectively. These results provide quite stringent constraints to wind models in low mass young stars, that need to be explored further.

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Complex organic molecules during low-mass star formation: Pilot survey results

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Complex organic molecules (COMs) are known to be abundant toward some low-mass young stellar objects (YSOs), but how these detections relate to typical COM abundance are not yet understood. We aim to constrain the frequency distribution of COMs during low-mass star formation, beginning with this pilot survey of COM lines toward six embedded YSOs using the IRAM 30m telescope. The sample was selected from the Spitzer c2d ice sample and covers a range of ice abundances. We detect multiple COMs, including CH$_3$CN, toward two of the YSOs, and tentatively toward a third. Abundances with respect to CH$_3$OH vary between 0.7 and 10%. This sample is combined with previous COM observations and upper limits to obtain a frequency distributions of CH$_3$CN, HCOOCH$_3$, CH$_3$OCH$_3$ and CH$_3$CHO. We find that for all molecules more than 50% of the sample have detections or upper limits of 1–10% with respect to CH$_3$OH. Moderate abundances of COMs thus appear common during the early stages of low-mass star formation. A larger sample is required, however, to quantify the COM distributions, as well as to constrain the origins of observed variations across the sample.

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Snow-lines as probes of turbulent diffusion in protoplanetary discs

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Sharp chemical discontinuities can occur in protoplanetary discs, particularly at ‘snow-lines’ where a gas-phase species freezes out to form ice grains. Such sharp discontinuities will diffuse out due to the turbulence suspected to drive angular momentum transport in accretion discs. We demonstrate that the concentration gradient - in the vicinity of the snow-line - of a species present outside a snow-line but destroyed inside is strongly sensitive to the level of turbulent diffusion (provided the chemical and transport time-scales are decoupled) and provides a direct measurement of the radial ‘Schmidt number’ (the ratio of the angular momentum transport to radial turbulent diffusion). Taking as an example the tracer species N$_2$H$^+$, which is expected to be destroyed inside the CO snow-line (as recently observed in
TW Hya) we show that ALMA observations possess significant angular resolution to constrain the Schmidt number. Since different turbulent driving mechanisms predict different Schmidt numbers, a direct measurement of the Schmidt number in accretion discs would allow inferences about the nature of the turbulence to be made.

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Young Stellar Population of the Bright-Rimmed Clouds BRC 5, BRC 7 and BRC 39

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Bright-rimmed clouds (BRCs), illuminated and shaped by nearby OB stars, are potential sites of recent/ongoing star formation. Here we present an optical and infrared photometric study of three BRCs: BRC 5, BRC 7 and BRC 39 to obtain a census of the young stellar population, thereby inferring the star formation scenario, in these regions. In each BRC, the Class I sources are found to be located mostly near the bright rim or inside the cloud, whereas the Class II sources are preferentially outside, with younger sources closer to the rim. This provides strong support to sequential star formation triggered by radiation driven implosion due to the UV radiation. Moreover, each BRC contains a small group of young stars being revealed at its head, as the next-generation stars. In particular, the young stars at the heads of BRC 5 and BRC 7 are found to be intermediate/high mass stars, which, under proper conditions, may themselves trigger further star birth, thereby propagating star formation out to long distances.

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Binaries in the field: fossils of the star formation process?

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Recent observations of binary stars in the Galactic field show that the binary fraction and the mean orbital separation both decrease as a function of decreasing primary mass. We present N-body simulations of the effects of dynamical evolution in star-forming regions on primordial binary stars to determine whether these observed trends can be explained by the dynamical processing of a common binary population. We find that dynamical processing of a binary population with an initial binary fraction of unity and an initial excess of intermediate/wide separation (100–10\textsuperscript{4} AU) binaries does not reproduce the observed properties in the field, even in initially dense (\sim 10\textsuperscript{3} M\odot pc\textsuperscript{-3}) star-forming regions.

If instead we adopt a field-like population as the initial conditions, most brown dwarf and M-dwarf binaries are dynamically hard and their overall fractions and separation distributions are unaffected by dynamical evolution. G-dwarf and A-star binaries in the field are dynamically intermediate in our simulated dense regions and dynamical processing does destroy some systems with separations >100 AU. However, the formation of wide binaries through the dissolution of supervirial regions is a strong function of primary mass, and the wide G-dwarf and A-star binaries that are destroyed by dynamical evolution in subvirial regions are replenished by the formation of binaries in supervirial regions. We therefore suggest that the binary population in the field is indicative of the primordial binary population.
in star-forming regions, at least for systems with primary masses in the range 0.02–3.0 $M_\odot$.

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Low-metallicity star formation: Relative impact of metals and magnetic fields

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Low-metallicity star formation poses a central problem of cosmology, as it determines the characteristic mass scale and distribution for the first and second generations of stars forming in our Universe. Here, we present a comprehensive investigation assessing the relative impact of metals and magnetic fields, which may both be present during low-metallicity star formation. We show that the presence of magnetic fields generated via the small-scale dynamo stabilises the protostellar disc and provides some degree of support against fragmentation. In the absence of magnetic fields, the fragmentation timescale in our model decreases by a factor of $\sim 10$ at the transition from $Z = 0$ to $Z > 0$, with subsequently only a weak dependence on metallicity. Similarly, the accretion timescale of the cluster is set by the large-scale dynamics rather than the local thermodynamics. In the presence of magnetic fields, the primordial disc can become completely stable, therefore forming only one central fragment. At $Z > 0$, the number of fragments is somewhat reduced in the presence of magnetic fields, though the shape of the mass spectrum is not strongly affected in the limits of the statistical uncertainties. The fragmentation timescale, however, increases by roughly a factor of 3 in the presence of magnetic fields. Indeed, our results indicate comparable fragmentation timescales in primordial runs without magnetic fields and $Z > 0$ runs with magnetic fields.

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Facing the wind of the pre-FUor V1331 Cyg

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The mass outflows in T Tauri stars (TTS) are thought to be an effective mechanism to remove angular momentum during the pre-main sequence contraction of a low mass star. The most powerful winds are observed at the FUor stage of stellar evolution. V1331 Cyg has been considered as a TTS at the pre-FUor stage. We analyze high-resolution spectra of V1331 Cyg collected in 1998-2007 and 20-days series of spectra taken in 2012. For the first time the photospheric spectrum of the star is detected and stellar parameters are derived: spectral type G7-K0 IV, mass 2.8 Msun, radius 5 Rsun, vsini < 6 km/s. The photospheric spectrum is highly veiled, but the amount of veiling is not the same in different spectral lines, being lower in weak transitions and much higher in strong transitions. The Fe II 5018, Mg I 5183, K I 7699 and some other lines of metals are accompanied by a ‘shell’ absorption at radial velocity of about -240 km/s. We show that these absorptions form in the post-shock gas in the jet, i.e. the star is seen through its jet. The P Cyg profiles of H-alpha and H-beta indicate the terminal wind velocity of about 500 km/s, which vary on timescales from several days to years. A model of the stellar wind is developed to interpret the observations. The model is based on calculation of hydrogen spectral lines using the radiative transfer code TORUS. The observed H-alpha and
H-beta line profiles and their variability can be well reproduced with a stellar wind model, where the mass-loss rate and collimation (opening angle) of the wind are variable. The changes of the opening angle may be induced by small variability in magnetization of the inner disc wind. The mass-loss rate is found to vary within \((6-11) \times 10^{-8}\) Msun/yr, with the accretion rate of \(2.0 \times 10^{-6}\) Msun/yr.

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**Hα emission-line stars in molecular clouds. II. The M42 region**

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We present a deep survey of H\(\alpha\) emission-line stars in the M42 region using wide-field objective prism films. A total of 1699 H\(\alpha\) emission-line stars were identified, of which 1025 were previously unknown, within an area of 5.5 x 5.5 degrees centred on the Trapezium Cluster. We present H\(\alpha\) strength estimates, positions, and JHK\(s\) photometry extracted from 2MASS, and comparisons to previous surveys. The spatial distribution of the bulk of the stars follows the molecular cloud as seen in CO and these stars are likely to belong to the very young population of stars associated with the Orion Nebula Cluster. Additionally, there is a scattered population of H\(\alpha\) emission-line stars distributed all over the region surveyed, which may consist partly of foreground stars associated with the young NGC 1980 cluster, as well as some foreground and background dMe or Be stars. The present catalogue adds a large number of candidate low-mass young stars belonging to the Orion population, selected independently of their infrared excess or X-ray emission.

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**Comparison of Prestellar Core Elongations and Large-scale Molecular Cloud Structures in the Lupus I Region**

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Turbulence and magnetic fields are expected to be important for regulating molecular cloud formation and evolution. However, their effects on subparsec to 100 parsec scales, leading to the formation of starless cores, are not well understood. We investigate the prestellar core structure morphologies obtained from analysis of the *Herschel*-SPIRE 350 \(\mu\)m maps of the Lupus I cloud. This distribution is first compared on a statistical basis to the large scale shape of the main filament. We find the distribution of the elongation position angle of the cores to be consistent with a random distribution, which means no specific orientation of the morphology of the cores is observed with respect to the mean orientation of the large-scale filament in Lupus I, nor relative to a large-scale bent filament model. This distribution is also compared to the mean orientation of the large-scale magnetic fields probed at 350 \(\mu\)m with the Balloon-borne Large Aperture Telescope for Polarimetry (BLASTPol) during its 2010 campaign. Here again we do not find any correlation between the core morphology distribution and the average orientation of the magnetic fields.
Giant molecular filaments in the Milky Way

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Throughout the Milky Way, molecular clouds typically appear filamentary, and mounting evidence indicates that this morphology plays an important role in star formation. What is not known is to what extent the dense filaments most closely associated with star formation are connected to the surrounding diffuse clouds up to arbitrarily large scales. How are these cradles of star formation linked to the Milky Way’s spiral structure? Using archival Galactic plane survey data, we have used multiple datasets in search of large-scale, velocity-coherent filaments in the Galactic plane. In this paper, we present our methods employed to identify coherent filamentary structures first in extinction and confirmed using Galactic Ring Survey data. We present a sample of seven Giant Molecular Filaments (GMFs) that have lengths of order ~100 pc, total masses of 10⁴ - 10⁵ M⊕, and exhibit velocity coherence over their full length. The GMFs we study appear to be inter-arm clouds and may be the Milky Way analogues to spurs observed in nearby spiral galaxies. We find that between 2 and 12% of the total mass (above ~10²⁰ cm⁻²) is “dense” (above 10²² cm⁻²), where filaments near spiral arms in the Galactic midplane tend to have higher dense gas mass fractions than those further from the arms.

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Massive Quiescent Cores in Orion: V. The Internal Structures, Physical and Chemical Properties of the Two Extremely Dense Cores

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We present a high-resolution (~ 1.5) arcsec observational study towards two massive dust-and-gas cores, ORI8nw, and ORI2, in Orion Molecular Cloud using the Combined Array for Research in Millimeter-wave Astronomy (CARMA). In each region the 3.2 mm continuum emission exhibits a dense and compact dust core at the center with 1 to 3 solar masses. The cores have number densities exceeding 10⁹ cm⁻³, which are among the highest volume densities observed in star-forming cores. In both regions the N₂H⁺ shows clumpy structures which are spatially displaced from the densest gas. In ORI8nw, in particular, the N₂H⁺ shows a noticeable filament structure with a central cavity shell. The calculation for the dynamical state shows that this core can be potentially supported by the magnetic field against its gravitational instability, but the fragmentation might still occur and produce the observed N₂H⁺ clumps if the gas density exceeds 5 × 10⁷ cm⁻³ and this value is available within the observed density range. And the extremely high density at the core center suggests the super-Jeans condition and possibility for further fragmentation. For the chemical properties, the N₂H⁺-to-HCO⁺ abundance ratios show a difference with that observed in infrared dark clouds. A combined analysis with the other Orion cores and the chemical model suggests that the different abundance ratios can be explained by the low CO abundances in our cores. To further reveal the evolution of such dense cores requires higher resolution and sensitivity.

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A CO observation of the Galactic methanol masers
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Using the 13.7-meter telescope at the Purple Mountain Observatory (PMO), we have obtained $^{12}$CO and $^{13}$CO (1 – 0) lines for 160 methanol masers sources from the first to the third Galactic quadrants. We made efforts to resolve the distance ambiguity by careful comparison with the radio continuum and HI 21 cm observations. We examined the statistical properties in three aspects: first, the variation throughout the Galaxy; second, the correlation between the different parameters; third, the difference between the maser sources and the infrared dark clouds. In addition, we have also carried out $^{13}$CO mapping for 33 sources in our sample. First, the maser sources show increased $^{13}$CO line widths toward the Galactic center, suggesting that the molecular gas are more turbulent toward the Galactic center. This trend can be noticeably traced by the $^{13}$CO line width. In comparison, the Galactic variation for the H\textsubscript{2} column density and the $^{12}$CO excitation temperature are less significant. Second, the $^{12}$CO excitation temperature shows a noticeable correlation with the H\textsubscript{2} column density. A possible explanation consistent with the collapse model is that the higher surface-density gas is more efficient to the stellar heating and/or has a higher formation rate of high-mass stars. Third, comparing the infrared dark clouds, the maser sources on average have significantly lower H\textsubscript{2} column densities, moderately higher temperatures, and similar line widths. Fourth, In the mapped regions around 33 masers, 51 $^{13}$CO cores have been revealed. Among them, only 17 coincide with the radio continuum emission ($F_{\text{cm}} > 6$ mJy), while a larger fraction (30 cores) coincide with the infrared emissions. Only one maser source has no significant IR emission. The IR-bright and radio-bright sources exhibit significantly higher $^{12}$CO excitation temperatures than the IR-faint and radio-faint sources, respectively. The 6.7 GHz masers show a moderately low ionization rate but have a common-existing stellar heating that generates the IR emissions. The relevant properties can be characterized by the $^{12}$CO and $^{13}$CO (1 – 0) emissions in several aspects as described above.

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Brown dwarf disks with ALMA
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We present ALMA continuum and spectral line data at 0.89 mm and 3.2 mm for three disks surrounding young brown dwarfs and very low mass stars in the Taurus star forming region. Dust thermal emission is detected and spatially resolved for all the three disks, while CO($J=3–2$) emission is seen in two disks. We analyze the continuum visibilities and constrain the disks physical structure in dust. The results of our analysis show that the disks are relatively large, the smallest one with an outer radius of about 70 AU. The inferred disk radii, radial profiles of the dust surface density and disk to central object mass ratios lie within the ranges found for disks around more massive young stars. We derive from our observations the wavelength dependence of the millimeter dust opacity. In all the three disks data are consistent with the presence of grains with at least millimeter sizes, as also found for disks around young stars, and confirm that the early stages of the solid growth toward planetesimals occur also around very low mass objects. We discuss the implications of our findings on models of solids evolution in protoplanetary disks, on the main mechanisms proposed for the formation of brown dwarfs and very low mass stars, as well as on the potential of finding rocky and giant planets around very low mass objects.
JVLA Observations of IC 348SW: Compact Radio Sources and their Nature
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We present sensitive 2.1 and 3.3 cm JVLA radio continuum observations of the region IC 348 SW. We detect a total of 10 compact radio sources in the region, of which seven are first reported here. One of the sources is associated with the remarkable periodic time-variable infrared source LRLL 54361, opening the possibility of monitoring this object at radio wavelengths. Four of the sources appear to be powering outflows in the region, including HH 211 and HH 797. In the case of the rotating outflow HH 797 we detect at its center a double radio source, separated by ∼ 3″. Two of the sources are associated with infrared stars that possibly have gyrosynchrotron emission produced in active magnetospheres. Finally, three of the sources are interpreted as background objects.

Gone with the wind: Where is the missing stellar wind energy from massive star clusters?
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Star clusters larger than ∼ 10^3 M_☉ contain multiple hot stars that launch fast stellar winds. The integrated kinetic energy carried by these winds is comparable to that delivered by supernova explosions, suggesting that at early times winds could be an important form of feedback on the surrounding cold material from which the star cluster formed. However, the interaction of these winds with the surrounding clumpy, turbulent, cold gas is complex and poorly understood. Here, we investigate this problem via an accounting exercise: we use empirically determined properties of four well-studied massive star clusters to determine where the energy injected by stellar winds ultimately ends up. We consider a range of kinetic energy loss channels, including radiative cooling, mechanical work on the cold interstellar medium, thermal conduction, heating of dust via collisions by the hot gas, and bulk advection of thermal energy by the hot gas. We show that, for at least some of the clusters, none of these channels can account for more than a small fraction of the injected energy. We suggest that turbulent mixing at the hot–cold interface or physical leakage of the hot gas from the H II region can efficiently remove the kinetic energy injected by the massive stars in young star clusters. Even for the clusters where we are able to account for all the injected kinetic energy, we show that our accounting sets strong constraints on the importance of stellar winds as a mechanism for feedback on the cold interstellar medium.

A necklace of dense cores in the high-mass star forming region G35.20−0.74N: ALMA observations
The present study aims at characterizing the massive star forming region G35.20N, which is found associated with at least one massive outflow and contains multiple dense cores, one of them recently found associated with a Keplerian rotating disk. We used ALMA to observe the G35.20N region in the continuum and line emission at 350 GHz. The observed frequency range covers tracers of dense gas (e.g. H$_{13}$CO$^+$, C$_{17}$O), molecular outflows (e.g. SiO), and hot cores (e.g. CH$_3$CN, CH$_3$OH). The ALMA 870 μm continuum emission map reveals an elongated dust structure (0.15 pc long and 0.013 pc wide) perpendicular to the large-scale molecular outflow detected in the region, and fragmented into a number of cores with masses 1–10 $M_\odot$ and sizes 1600 AU. The cores appear regularly spaced with a separation of 0.023 pc. The emission of dense gas tracers such as H$_{13}$CO$^+$ or C$_{17}$O is extended and coincident with the dust elongated structure. The three strongest dust cores show emission of complex organic molecules characteristic of hot cores, with temperatures around 200 K, and relative abundances $0.2\times10^{-8}$ for CH$_3$CN and $0.6\times10^{-6}$ for CH$_3$OH. The two cores with highest mass (cores A and B) show coherent velocity fields, with gradients almost aligned with the dust elongated structure. Those velocity gradients are consistent with Keplerian disks rotating about central masses of 4–18 $M_\odot$. Perpendicular to the velocity gradients we have identified a large-scale precessing jet/outflow associated with core B, and hints of an east-west jet/outflow associated with core A. The elongated dust structure in G35.20N is fragmented into a number of dense cores that may form massive stars. Based on the velocity field of the dense gas, the orientation of the magnetic field, and the regularly spaced fragmentation, we interpret this elongated structure as the densest part of a 1D filament fragmenting and forming massive stars.

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Water distribution in shocked regions of the NGC1333-IRAS4A protostellar outflow

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Water is a key molecule in protostellar environments because its line emission is very sensitive to both the chemistry and the physical conditions of the gas. Observations of H$_2$O line emission from low-mass protostars and their associated outflows performed with HIFI onboard the Herschel Space Observatory have highlighted the complexity of H$_2$O line profiles, in which different kinematic components can be distinguished. The goal is to study the spatial distribution of H$_2$O, in particular of the different kinematic components detected in H$_2$O emission, at two bright shocked regions along IRAS4A, one of the strongest H$_2$O emitters among the Class 0 outflows. We obtained Herschel-PACS maps of the IRAS4A outflow and HIFI observations of two shocked positions. The largest HIFI beam of 38" at 557 GHz was mapped in several key water lines with different upper energy levels, to reveal possible spatial variations of the line profiles. We detect four H$_2$O lines and CO (16−15) at the two selected shocked positions. In addition, transitions from related outflow and envelope tracers are detected. Different gas components associated with the shock are identified in the H$_2$O emission. In particular, at the head of the red lobe of the outflow, two distinct gas components with different excitation conditions are distinguished in the HIFI emission maps: a compact component, detected in the ground-state water lines, and a more extended one. Assuming that these two components correspond to two different temperature components observed in previous H$_2$O and CO studies, the IVG analysis of the H$_2$O emission suggests that the compact (about 3") component, corresponding to about 700 AU) component is associated with a hot (T∼1000 K) gas with densities $n_{\text{H}_2}\sim(1-4)\times10^5$ cm$^{-3}$, whereas the extended (10$^7$−17", corresponding to 2400−4000 AU) one traces a warm (T∼300−500 K) and dense gas ($n_{\text{H}_2}\sim(3-5)\times10^7$ cm$^{-3}$). Finally, using the CO (16−15) emission observed at R2 and assuming a typical CO/H$_2$ abundance of $10^{-4}$, we estimate the H$_2$O/H$_2$ abundance of the warm and hot components to be $(7-10)\times10^{-7}$ and $(3-7)\times10^{-5}$. Our data allowed us, for the first time, to resolve spatially the two temperature components previously observed with HIFI and PACS. We propose that the compact hot component may be associated with the jet that impacts the surrounding material, whereas the warm, dense, and extended component originates from the compression of the ambient gas by the propagating flow.

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The Gaia-ESO Survey: metallicity of the Chamaeleon I star forming region


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Context. Recent metallicity determinations in young open clusters and star-forming regions suggest that the latter may be characterized by a slightly lower metallicity than the Sun and older clusters in the solar vicinity. However, these results are based on small statistics and inhomogeneous analyses. The Gaia-ESO Survey is observing and homogeneously analyzing large samples of stars in several young clusters and star-forming regions, hence allowing us to further investigate this issue.

Aims. We present a new metallicity determination of the Chamaeleon I star-forming region, based on the products distributed in the first internal release of the Gaia-ESO Survey.

Methods. 48 candidate members of Chamaeleon I have been observed with the high-resolution spectrograph UVES. We use the surface gravity, lithium line equivalent width and position in the Hertzsprung-Russell diagram to confirm the cluster members and we use the iron abundance to derive the mean metallicity of the region.

Results. Out of the 48 targets, we confirm 15 high probability members. Considering the metallicity measurements for 9 of them, we find that the iron abundance of Chamaeleon I is slightly subsolar with a mean value $[\text{Fe/H}] = -0.08 \pm 0.04$ dex. This result is in agreement with the metallicity determination of other nearby star-forming regions and suggests that the chemical pattern of the youngest stars in the solar neighborhood is indeed more metal-poor than the Sun. We argue that this evidence may be related to the chemical distribution of the Gould Belt that contains most of the nearby star-forming regions and young clusters.

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Disk Dissipation Timescale of Pre-main Sequence Stars in Taurus

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We present the results of an age determination study of pre-main sequence stars in the Taurus star-forming region. The ages of 10 single stars with masses of 0.5–1.1 $M_{\odot}$ were derived from the surface gravities, estimated from high-resolution optical and near-infrared spectroscopy. The equivalent width ratios of nearby absorption line pairs were employed for the surface gravity diagnostic, which directly reflects the parameters of the stellar atmosphere without any veiling correction. From a comparison of determined ages and near-infrared color excesses such as $J - H$, $J - K$, and $J - L$, the inner disk lifetime of the young stars with 0.5–1.1 $M_{\odot}$ in Taurus is estimated to be 3–4 Myr.

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Deuteration around the ultracompact HII region Mon R2

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The massive star-forming region Mon R2 hosts the closest ultra-compact HII region that can be spatially resolved with current single-dish telescopes. We used the IRAM-30m telescope to carry out an unbiased spectral survey toward two important positions (namely IF and MP2), in order to studying the chemistry of deuterated molecules toward Mon R2. We found a rich chemistry of deuterated species at both positions, with detections of C$_2$D, DCN, DNC, DCO$^+$, D$_2$CO, HDCO, NH$_2$D, and N$_2$D$^+$ and their corresponding hydrogenated species and isotopologs. Our high spectral resolution observations allowed us to resolve three velocity components: the component at 10 km s$^{-1}$ is detected at both positions and seems associated with the layer most exposed to the UV radiation from IRS 1; the component at 12 km s$^{-1}$ is found toward the IF position and seems related to the molecular gas; finally, a component at 8.5 km s$^{-1}$ is only detected toward the MP2 position, most likely related to a low-UV irradiated PDR. We derived the column density of all the species, and determined the deuterium fractions ($D_{\text{frac}}$). The values of $D_{\text{frac}}$ are around 0.01 for all the observed species, except for HCO$^+$ and N$_2$H$^+$ which have values 10 times lower. The values found in Mon R2 are well explained with pseudo-time-dependent gas-phase model in which deuteration occurs mainly via ion-molecule reactions with H$_2$D$^+$, CH$_2$D$^+$ and C$_2$HD$^+$. Finally, the [H$^{13}$CN]/[HN$^{13}$C] ratio is very high ($\sim$11) for the 10 km s$^{-1}$ component, which also agree with our model predictions for an age of $\sim$0.01–0.1 Myr. The deuterium chemistry is a good tool for studying star-forming regions. The low-mass star-forming regions seem well characterized with $D_{\text{frac}}$(N$_2$H$^+$) or $D_{\text{frac}}$(HCO$^+$), but it is required a complete chemical modeling to date massive star-forming regions, because the higher gas temperature together with the rapid evolution of massive protostars.

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to massive clumps found in the submillimetre ATLASGAL survey, we have identified $\sim$1000 embedded young massive stars between $280^\circ < l < 350^\circ$ and $10^\circ < l < 60^\circ$ with $|b| < 1.5^\circ$. Combined with an existing sample of radio-selected methanol masers and compact HII regions, the result is a catalogue of $\sim$1700 massive stars embedded within $\sim$1300 clumps located across the inner Galaxy, containing three observationally distinct subsamples, methanol-maser, MYSO and HII-region associations, covering the most important tracers of massive star formation, thought to represent key stages of evolution. We find that massive star formation is strongly correlated with the regions of highest column density in spherical, centrally condensed clumps. We find no significant differences between the three samples in clump structure or the relative location of the embedded stars, which suggests that the structure of a clump is set before the onset of star formation, and changes little as the embedded object evolves towards the main sequence. There is a strong linear correlation between clump mass and bolometric luminosity, with the most massive stars forming in the most massive clumps. We find that the MYSO and HII-region subsamples are likely to cover a similar range of evolutionary stages and that the majority are near the end of their main accretion phase. We find few infrared-bright MYSOs associated with the most massive clumps, probably due to very short pre-main sequence lifetimes in the most luminous sources.

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Analysis of 1SWASP J140747.93-394542.6 eclipse fine-structure: hints of exomoons
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A recently discovered $V = 12.3$ mag K5 pre-main-sequence star in the SuperWASP (Super Wide Angle Search for Planets) data base shows a peculiar light curve with a highly structured eclipse pattern covering a timespan of at least 54d with maximum dimming of at least 3.3 mag. The central eclipse is surrounded by two 1 mag eclipses at $\pm 12$ and $\pm 26$ d. The authors speculate that the star is eclipsed by a substellar companion with an extended and highly structured ring system. To investigate the nightly light-curve structure and to confirm the multiple-ring hypothesis, we have carried out a calibrated reduction of the SuperWASP data, removing both systematic errors and periodic stellar variability. We count at least 24 inflection points on ingress and 16 on egress, consistent with the presence of at least 24 rings in this disc. By measuring the light-curve slope, we find implied speeds for the eclipsing object that are incompatible with a closed Kepler orbit with $P = 2.3$ yr. We propose several scenarios that could give rise to such light-curve slopes and find that azimuthal ring structure (analogous to 'spokes' seen in Saturn’s rings) can account for the observed light curve. The highly structured ring system also implies the presence of exomoons orbiting the secondary companion.

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Cosmic ray induced ionisation of a molecular cloud shocked by the W28 supernova remnant
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Cosmic rays are an essential ingredient in the evolution of the interstellar medium, as they dominate the ionisation of the dense molecular gas, where stars and planets form. However, since they are efficiently scattered by the galactic magnetic fields, many questions remain open, such as where exactly they are accelerated, what is their original energy spectrum, and how they propagate into molecular clouds. In this work we present new observations and discuss in detail a method that allows us to measure the cosmic ray ionisation rate towards the molecular clouds close to the W28 supernova.
remnant. To perform these measurements, we use CO, HCO+, and DCO+ millimetre line observations and compare them with the predictions of radiative transfer and chemical models away from thermodynamical equilibrium. The CO observations allow us to constrain the density, temperature, and column density towards each observed position, while the DCO+/HCO+ abundance ratios provide us with constraints on the electron fraction and, consequently, on the cosmic ray ionisation rate. Towards positions located close to the supernova remnant, we find cosmic ray ionisation rates much larger (≥100) than those in standard galactic clouds. Conversely, towards one position situated at a larger distance, we derive a standard cosmic ray ionisation rate. Overall, these observations support the hypothesis that the γ rays observed in the region have a hadronic origin. In addition, based on CR diffusion estimates, we find that the ionisation of the gas is likely due to 0.1 – 1 GeV cosmic rays. Finally, these observations are also in agreement with the global picture of cosmic ray diffusion, in which the low-energy tail of the cosmic ray population diffuses at smaller distances than the high-energy counterpart.

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Kinematical fingerprints of star cluster early dynamical evolution

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We study the effects of the external tidal field on the violent relaxation phase of star clusters dynamical evolution, with particular attention to the kinematical properties of the equilibrium configurations emerging at the end of this phase. We show that star clusters undergoing the process of violent relaxation in the tidal field of their host galaxy can acquire significant internal differential rotation and are characterized by a distinctive radial variation of the velocity anisotropy. These kinematical properties are the result of the symmetry breaking introduced by the external tidal field in the collapse phase and of the action of the Coriolis force on the orbit of the stars. The resulting equilibrium configurations are characterized by differential rotation, with a peak located between one and two half-mass radii. As for the anisotropy, similar to clusters evolving in isolation, the systems explored in this Letter are characterized by an inner isotropic core, followed by a region of increasing radial anisotropy. However, for systems evolving in an external tidal field the degree of radial anisotropy reaches a maximum in the cluster intermediate regions and then progressively decreases, with the cluster outermost regions being characterized by isotropy or a mild tangential anisotropy. Young or old but less-relaxed dynamically young star clusters may keep memory of these kinematical fingerprints of their early dynamical evolution.

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Formation of Isothermal Disks around Protoplanets. I. Introductory Three-Dimensional Global Simulations for Sub-Neptune-Mass Protoplanets

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The regular satellites found around Neptune (≈ 17 M⊕) and Uranus (≈ 14.5 M⊕) suggest that past gaseous circumplanetary disks may have co-existed with solids around sub-Neptune-mass protoplanets (< 17 M⊕). These disks have been shown to be cool, optically thin, quiescent, with low surface density and low viscosity. Numerical studies of the
formation are difficult and technically challenging. As an introductory attempt, three-dimensional global simulations
are performed to explore the formation of circumplanetary disks around sub-Neptune-mass protoplanets embedded
within an isothermal protoplanetary disk at the inviscid limit of the fluid in the absence of self-gravity. Under such
conditions, a sub-Neptune-mass protoplanet can reasonably have a rotationally supported circumplanetary disk. The
size of the circumplanetary disk is found to be roughly one-tenth of the corresponding Hill radius, which is consistent
with the orbital radii of irregular satellites found for Uranus. The protoplanetary gas accretes onto the circumplanetary
disk vertically from high altitude and returns to the protoplanetary disk again near the midplane. This implies
an open system in which the circumplanetary disk constantly exchanges angular momentum and material with its
surrounding prenatal protoplanetary gas.

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Cold Water Vapor in the Barnard 5 Molecular Cloud
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After more than 30 years of investigations, the nature of gas-grain interactions at low temperatures remains an
unresolved issue in astrochemistry. Water ice is the dominant ice found in cold molecular clouds, however, there is
only one region where cold (∼10 K) water vapor has been detected - L1544. This study aims to shed light on ice
desorption mechanisms under cold cloud conditions by expanding the sample.
The clumpy distribution of methanol in dark clouds testifies to transient desorption processes at work – likely to also
disrupt water ice mantles. Therefore, the Herschel HIFI instrument was used to search for cold water in a small sample
of prominent methanol emission peaks. We report detections of the ground-state transition of \( \text{o-H}_2\text{O} \) \((J = 1\text{_{10}} - 1\text{_{01}})\) at
556.9360 GHz toward two positions in the cold molecular cloud Barnard 5. The relative abundances of methanol and
water gas support a desorption mechanism which disrupts the outer ice mantle layers, rather than causing complete
mantle removal.

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Deep optical survey of the stellar content of Sh2-311 region
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The stellar content in and around Sh2-311 region have been studied using the deep optical observations as well as near-infrared (NIR) data from 2MASS. The region contains three clusters, viz. NGC 2467, Haffner 18 and Haffner 19. We have made an attempt to distinguish the stellar content of these individual regions as well as to re-determine their fundamental parameters such as distance, reddening, age, onto the basis of a new and more extended optical and infrared photometric data set. NGC 2467 and Haffner 19 are found to be located in the Perseus arm at the distances of $5.0 \pm 0.4$ kpc and $5.7 \pm 0.4$ kpc, respectively, whereas Haffner 18 is located at the distance of $11.2 \pm 1.0$ kpc. The clusters NGC 2467 and Haffner 19 might have formed from the same molecular cloud, whereas the cluster Haffner 18 is located in the outer galactic arm, i.e. the Norma-Cygnus arm. We identify 8 class II young stellar objects (YSOs) using the NIR $(J-H)/(H-K)$ two colour diagram. We have estimated the age and mass of the YSOs identified in the present work and those by Snider et al. (2009) using the $V/(V-I)$ colour-magnitude diagram. The estimated ages and mass range of the majority of the YSOs are $<1$ Myr and $\sim0.4 - 3.5 \, M_\odot$, respectively, indicating that these sources could be T-Tauri stars or their siblings. Spatial distribution of the YSOs shows that some of the YSOs are distributed around the H II region Sh2-311, suggesting a triggered star formation at its periphery.

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YSO search toward the boundary of the Central Molecular Zone with near-infrared polarimetry

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We have carried out near-infrared polarimetry toward the boundary of the Central Molecular Zone, in the field of $(-1.3^\circ < l < -0.3^\circ$ and $1.7^\circ < l < 2.5^\circ$, $|b| < 0.1^\circ$), using the near-infrared polarimetric camera SIRPOL on the 1.4 m Infrared Survey Facility telescope. We have selected 112 intrinsically polarized sources on the basis of the estimate of interstellar polarization on Stokes $Q/I - U/I$ planes. The selected sources are brighter than $K_S = 14.5$ mag and have polarimetric uncertainty $\delta P < 1$. Ten of these distinctive polarized sources are fit well with spectral energy distributions of young stellar objects when using the photometry in the archive of the Spitzer Space Telescope mid-infrared data. However, many sources have spectral energy distributions of normal stars suffering heavy interstellar extinction; these might be stars behind dark clouds. Due to the small number of distinctive polarized sources and candidates of young stellar object, we cannot judge if there is a decline of them outside the Central Molecular Zone. Many of massive candidates of young stellar object in the literature have only small intrinsic polarization. This might suggest that their masses are 4–15 $M_\odot$, whose intrinsic polarization has been expected to be small.

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Resonances of Multiple Exoplanets and Implications for Their Formation

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Among \(\sim 160\) of the multiple exoplanetary systems confirmed, about 30\% of them have neighboring pairs with a period ratio \(\leq 2\). A significant fraction of these pairs are around mean motion resonance (MMR), more interestingly, peak around 2:1 and 3:2, with a clear absence of more closely packed MMRs with period ratios less than 4:3, regardless of planet masses. Here we report numerical simulations demonstrating that such MMR behavior places important constraints on the disk evolution stage out of which the observed planets formed. Multiple massive planets (with mass \(\geq 0.8\, M_{\text{Jup}}\)) tend to end up with a 2:1 MMR mostly independent of the disk masses but low-mass planets (with mass \(\leq 30\, M_{\oplus}\)) can have MMRs larger than 4:3 only when the disk mass is quite small, suggesting that the observed dynamical architecture of most low-mass-planet pairs was established late in the disk evolution stage, just before it was dispersed completely.

Accepted by ApJL


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**Moving ... ??**

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Global Models of Planet Formation and Evolution
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Despite the increase in observational data on exoplanets, the processes that lead to the formation of planets are still not well understood. But thanks to the high number of known exoplanets, it is now possible to look at them as a population that puts statistical constraints on theoretical models. A method that uses these constraints is planetary population synthesis. Its key element is a global model of planet formation and evolution that directly predicts observable planetary properties based on properties of the natal protoplanetary disk. To do so, global models build on many specialized models that address one specific physical process. We thoroughly review the physics of the submodels included in global formation models. The sub-models can be classified as models describing the protoplanetary disk (gas and solids), the (proto)planet (solid core, gaseous envelope, and atmosphere), and finally the interactions (migration and N-body interaction). We compare the approaches in different global models and identify physical processes that require improved descriptions in future. We then address important results of population synthesis like the planetary mass function or the mass-radius relation. In these results, the global effects of physical mechanisms occurring during planet formation and evolution become apparent, and specialized models describing them can be put to the observational test. Due to their nature as meta models, global models depend on the development of the field of planet formation theory as a whole. Because there are important uncertainties in this theory, it is likely that global models will in future undergo significant modifications. Despite this, they can already now yield many testable predictions. With future global models addressing the geophysical characteristics, it should eventually become possible to make predictions about the habitability of planets.

Accepted by International Journal of Astrobiology


Empirical Tests of Pre-Main-Sequence Stellar Evolution Models with Eclipsing Binaries
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We examine the performance of standard PMS stellar evolution models against the accurately measured properties of a benchmark sample of 26 PMS stars in 13 EB systems. We provide a definitive compilation of all fundamental properties for the EBs. We also provide a definitive compilation of the various PMS model sets. In the H-R diagram, the masses inferred for the individual stars by the models are accurate to better than 10% above 1 M☉, but below 1 M☉ they are discrepant by 50–100%. We find evidence that the failure of the models to match the data is linked to the triples in the EB sample; at least half of the EBs possess tertiary companions. Excluding the triples, the models reproduce the stellar masses to better than ~10% in the H-R diagram, down to 0.5 M☉, below which the current sample is fully contaminated by tertiaries. We consider several mechanisms by which a tertiary might cause changes
in the EB properties and thus corrupt the agreement with stellar model predictions. We show that the energies of the tertiary orbits are comparable to that needed to potentially explain the scatter in the EB properties through injection of heat, perhaps involving tidal interaction. It seems from the evidence at hand that this mechanism, however it operates in detail, has more influence on the surface properties of the stars than on their internal structure, as the lithium abundances are broadly in good agreement with model predictions. The EBs that are members of young clusters appear individually coeval to within 20%, but collectively show an apparent age spread of ~50%, suggesting true age spreads in young clusters. However, this apparent spread in the EB ages may also be the result of scatter in the EB properties induced by tertaries.

Accepted by New Astronomy Reviews
http://arxiv.org/pdf/1406.3788

Planet formation in Binaries
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Spurred by the discovery of numerous exoplanets in multiple systems, binaries have become in recent years one of the main topics in planet formation research. Numerous studies have investigated to what extent the presence of a stellar companion can affect the planet formation process. Such studies have implications that can reach beyond the sole context of binaries, as they allow to test certain aspects of the planet formation scenario by submitting them to extreme environments. We review here the current understanding on this complex problem. We show in particular how each of the different stages of the planet-formation process is affected differently by binary perturbations. We focus especially on the intermediate stage of kilometre-sized planetesimal accretion, which has proven to be the most sensitive to binarity and for which the presence of some exoplanets observed in tight binaries is difficult to explain by in-situ formation following the "standard" planet-formation scenario. Some tentative solutions to this apparent paradox are presented. The last part of our review presents a thorough description of the problem of planet habitability, for which the binary environment creates a complex situation because of the presence of two irradiation sources of varying distance.

Accepted by Planetary Exploration and Science: Recent Advances and Applications

Complex organic molecules along the accretion flow in isolated and externally irradiated protoplanetary disks
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The birth environment of the Sun will have influenced the conditions in the pre-solar nebula, including the attainable chemical complexity, important for prebiotic chemistry. The formation and distribution of complex organic molecules (COMs) in a disk around a T Tauri star is investigated for two scenarios: (i) an isolated disk, and (ii) a disk irradiated externally by a nearby massive star. The chemistry is calculated along the accretion flow from the outer disk inwards using a comprehensive network. Two simulations are performed, one beginning with complex ices and one with simple ices only. For the isolated disk, COMs are transported without major alteration into the inner disk where they
thermally desorb into the gas reaching an abundance representative of the initial assumed ice abundance. For simple ices, COMs efficiently form on grain surfaces under the conditions in the outer disk. Gas-phase COMs are released into the molecular layer via photodesorption. For the irradiated disk, complex ices are also transported inwards; however, they undergo thermal processing caused by the warmer conditions in the irradiated disk which tends to reduce their abundance along the accretion flow. For simple ices, grain-surface chemistry cannot synthesise COMs in the outer disk because the necessary grain-surface radicals, which tend to be particularly volatile, are not sufficiently abundant on the grain surfaces. Gas-phase COMs are formed in the inner region of the irradiated disk via gas-phase chemistry induced by the desorption of strongly bound molecules such as methanol; hence, the abundances are not representative of the initial molecular abundances injected into the outer disk. These results suggest that the composition of comets formed in isolated disks may differ from those formed in externally irradiated disks with the latter composed of more simple ices.

Accepted by Faraday Discussion

Filamentary structures in interstellar molecular clouds have long been recognised as an important part of the star formation process. Recent studies have confirmed that dense cores in different stages of star formation are commonly located in the filaments. Therefore, it is important to study the structure and formation of the filaments and the cores, to understand the details of the early phases of star formation. The density structure of molecular clouds can be studied using many different methods and wavelengths. All techniques have their own drawbacks, and, therefore, it is crucial to compare the results obtained with different methods. Before making conclusions on observational data, the observational uncertainties and biases should be evaluated with simulations. This thesis concentrates on comparing simulations and observations of the early, prestellar phase of star formation. It consists of five journal articles.

In two of the articles, we use large magnetohydrodynamical simulations followed by radiative transfer calculations to estimate the observational biases of the properties of interstellar dust, filaments and cores. We conclude that for normal stable cores the derived core masses are precise to some tens of percent, using correct assumptions of the dust properties. For high-density cores, the derived masses can be severely underestimated, up to one order of magnitude. However, an internal radiation source can make the dust in the core centre visible again, diminishing the observational bias. We also estimate the observational biases of dust emissivity properties. The parameters describing the filament cross-section, i.e. profile, are sensitive to noise but, for nearby clouds, can be determined with good accuracy using, e.g., Herschel data. However, line-of-sight confusion may complicate the observations, as part of the observed filaments are not physically continuous structures.

In two of the articles, we compare three observational methods, namely observations of dust emission, extinction, and near-infrared (NIR) scattering, to study the properties of interstellar filaments. We conclude that NIR extinction maps can be used as an alternative or a complementary method to evaluate filament structure. Direct fits to the extinction of individual stars can also serve as a valuable new tool in profiling. The filament profile parameters can be best constrained by combining observations of dust emission and extinction. NIR scattering can be a useful method to produce high-resolution maps even in relatively large areas, at the scale of a complete filament. However, observations of scattered NIR light can be complicated.

In the last article, we use multiwavelength observations to study the high Galactic latitude cloud L1642. The cloud reveals a more complex structure and sequence of star formation than previously known. Our results also demonstrate the importance of combining sub-millimetre Herschel data with millimetre Planck data in constraining the estimates of dust properties.


POSTDOCTORAL FELLOWSHIP IN STAR FORMATION

The INAF-Osservatorio Astrofisico di Arcetri invites applications for a postdoctoral position in the area of star formation. The fellow will work with Dr. Maite Beltran and collaborators, within the iALMA funded project, on high-angular resolution observational studies of complex organic molecules in star-forming regions. He or she will plan and execute high-angular resolution observations of complex molecules in star-forming regions (of low- and high-mass and from pre-stellar cores to planetary systems) using single-dish antennas, such as IRAM 30-m, and interferometers, such as ALMA, IRAM PdBI, SMA and VLA. He or she will analyse and interpret PdBI and ALMA observations using the GILDAS and CASA data reduction tools, and the available spectroscopic catalogues (JPL, CDMS, NIST).

He or she will discuss and prepare projects to be carried out with Band 2, which should be implemented in ALMA in the near future.

The Research fellowship is expected to begin as soon as possible but not later than December 2014, for a period of 24 months, with a possible extension depending on performance and funding availability. The gross annual salary will be 30,000.00 Euro. This amount is net of burdens to be charged to INAF-Arcetri, social charges and will be paid in deferred monthly instalments. More information can be found at the fellowship official call site
http://www.arcetri.astro.it/BillBoards/posti/ATC-344fa8fa0-001.pdf

The applicant must have a Ph.D. in Astronomy or Physics. Research experience in (sub-)millimeter astronomy and interferometric observations, knowledge of galactic star formation and chemistry of the interstellar medium, and independent and collaborative research skills are desirable.

Applications are to be submitted by and not after August 20th, 2014. Late submissions will not be considered. Application form and instructions can be found at the fellowship official call site. Applications must be submitted in English as closed envelope by 'Raccomandata A/R', authorized carrier (ex. DHL, FedEx, UPS, etc.) or, in person, at the Office Protocol to the address INAF-Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, 50125 Firenze (ITALY). Alternatively, the application can be submitted using PEC (Posta Elettronica Certificata: no ordinary e-mail) to the following PEC address: inafoarcteti@pcert.postecert.it.

Applicant should also arrange for two signed letters of reference by persons familiar with her/his work who shall send them directly and within the deadline by e-mail with acknowledgement of receipt to the following address: mbeltran@arcetri.astro.it. It is also recommended to send an email to the same address to notify the submission of the application.
First announcement

From Protoplanetary Disks to Planet Formation

45th Saas-Fee “Advanced Course”
of the Swiss Society for Astrophysics and Astronomy

Les Diablerets, Switzerland
15-20 March 2015

http://isdc.unige.ch/sf2015

Since 1971 the Swiss Society for Astrophysics and Astronomy has been organizing Saas-Fee advanced course in astrophysics. The topic for the 2015 course will be:

From Protoplanetary Disks to Planet Formation

The course will take place from 15-20 March 2015 in the Swiss ski resort, Les Diablerets. In the tradition of Saas-Fee courses, three topics will be presented by three speakers for a total of 24 lectures:

- Processes in protoplanetary disks: Prof. Philip J. Armitage
- Observational properties of protoplanetary disks: Dr. Leonardo Testi
- Planet formation and disk-planet interactions: Prof. Willhelm Kley

The course will, thus, cover the theoretical and observational properties of protoplanetary disks leading to the formation of planets. The main audience of the course is PhD students, postdoctoral scientists from the international community. Members of the SSAA are also welcome. Free time is left in the afternoon for interactions, discussions, skiing, snowshoeing, etc.

Registration will open in September 2014 and the number of participants will be limited to about 100 participants.

More details can be found on the course website:

http://isdc.unige.ch/sf2015

Organizers: Marc Audard (University of Geneva), Yann Alibert (University of Bern), Michael R. Meyer (ETH Zurich), and Martine Logossou (University of Geneva)

contact: sf2015@unige.ch
The Early Life of Stellar Clusters: Formation and Dynamics
3-7 November 2014, Copenhagen, Denmark
http://www.nbia.dk/nbia-clusters-2014

The goal of the workshop is to bridge the artificial divide between the fields of star formation and stellar dynamics. Star formation provides the initial conditions for the long term evolution of stellar clusters, while the dynamics of stars in clusters after star formation has ceased can inform on the conditions that have prevailed in the environment in which the clusters have formed. The central topics of the workshop will thus focus on:

- Reviewing the status of observations of star forming regions and young stellar clusters and discuss the prospects with current and future ground based and space-borne telescopes
- Characterizing the dependence of the IMF, the SFE, binarity, sub-clustering, mass segregation, ages spreads on the environment in which stars form
- Exploring the effects of any variability in the outcome of the star formation process on the dynamical evolution of stellar clusters.
- Assessing the importance of the different modes of stellar feedback and highlighting their importance on the clusters SFE, dynamics, and survival
- Discussing the advances in the numerical modeling of star formation and the dynamical evolution of stellar clusters and the necessity of having platforms that integrate all the required physics.

Workshop Organisers:
Sami Dib (NBIA & StarPlan)
Paolo Padoan (ICC, Barcelona)
Simon Portegies Zwart (Leiden)
Susanne Pfalzner (MPIfR, Bonn)
Barbara Ercolano (USM, Munich)
Inti Pelupessy (Leiden)
Seyit Höckük (Groningen)
Troels Haugbile (StarPlan & NBI)
EWASS 2015

Call for Expressions of Interest to organise Symposia and Special Sessions

The European Week of Astronomy and Space Science (EWASS 2015) will take place in La Laguna, in Tenerife, Canary Islands, Spain, from 22 - 26 June 2015. The meeting will be organised at the University of La Laguna’s Guajara Campus by the European Astronomical Society (EAS), in collaboration with the Spanish Astronomical Society (SEA), the Instituto de Astrofisica de Canarias, and the Universidad de La Laguna.

We now invite proposals from colleagues who are interested in organising a Symposium or a Special Session.

A broad range of parallel sessions can be accommodated as:

(A) Symposia which normally consist of up to 6 blocks of 1.5 hours, stretching over 2 days, although exceptionally and in well-justified cases these symposia can be slightly longer, (B) Special Sessions consisting of up to 3 blocks of 1.5 hours on the same day. Proposers should strive to make their proposals of interest to large fractions of the European astronomical community. All proposals should be submitted as plain text email, with of the order of 500 words, and should include the following information:

Title and type of proposed session Summary of the goal(s) of the session Names of organisers (at least two persons) Justification for proposed duration of the session (how many 1.5-hour blocks?) Anticipated audience size Possible review talks and possible speakers Whether or not you plan to accept posters Organisers of EWASS sessions are benefitting from the logistic support of the EWASS conference including the disposal of the venue room, registration handling, the portal for abstract submission and reviewing, and the hosting of a web page on the EWASS website. Organisers should not count on additional support from EWASS for attending the conference, neither for themselves nor for their invited speakers.

Note that the IAU has already selected the Symposia and Focus Meetings for the IAU General Assembly in Hawaii, in August 2015, see http://www.iau.org/science/meetings/future/

Proposals should be sent to the SOC Chairs: Cathie Clarke (cclarke@ast.cam.ac.uk) and Johan Knapen (jhk@iac.es), for review by the SOC.

Applicants will be notified in September about the outcome of the selection. Individuals within the European Astronomy and Space Science communities, as well as EU sponsored networks, are strongly encouraged to propose and organise sessions.

The deadline for submitting Expressions of Interest is: Friday, 1 August 2014.
Summary of Upcoming Meetings

Workshop on Dense Cores: Origin, Evolution, and Collapse
27 - 30 July 2014 Monterey, CA, USA
http://www.aas.org/meetings/aastcs4

Characterizing Planetary Systems Across the HR Diagram
28 July - 1 August 2014 Inst. for Astronomy, Cambridge, USA
http://www.ast.cam.ac.uk/meetings/2013/AcrossHR

StarBench-II: A Workshop for Benchmarking Star Formation Codes
1 - 5 September 2014 Bonn, Germany
http://www.astro.uni-bonn.de/sb-ii/

Planet Formation and Evolution 2014
8 - 10 September 2014 Kiel, Germany
http://www.astrophysik.uni-kiel.de/kiel2014

Living Together: Planets, Stellar Binaries and Stars with Planets
8 - 12 September 2014 Litomysl Castle, Litomysl, Czech Republic

Galactic and Extragalactic Star Formation
8 - 12 September 2014 Marseille, France

Thirty Years of Beta Pic and Debris Disk Studies
8 - 12 September 2013 Paris, France
http://betapic30.sciencesconf.org

Towards Other Earths II. The Star-Planet Connection
15 - 19 September 2014 Portugal

Filamentary Structure in Molecular Clouds
10 - 11 October 2014 Charlottesville, USA
https://science.nrao.edu/science/meetings/2014/filamentary-structure/

The Early Life of Stellar Clusters: Formation and Dynamics
3 - 7 November 2014, Copenhagen, Denmark
http://www.nbia.dk/nbia-clusters-2014

Star Formation Across Space and Time
11-14 November 2014 Noordwijk, The Netherlands
http://congrexprojects.com/14a09/

Triple Evolution & Dynamics in Stellar and Planetary Systems
15 - 21 November 2014 Haifa, Israel
http://trendy-triple.weebly.com

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

The Soul of Massive Star Formation
15 - 20 March 2015 Puerto Varas, Chile
http://www.das.uchile.cl/msf2015/
Star and Planet Formation in the Southwest
23 - 27 March 2015 Oracle, Arizona, USA
no website yet

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

Extreme Solar Systems III
29 November - 4 December 2015 Hawaii, USA
http://ciera.northwestern.edu/Hawaii2015.php

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

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