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Abstracts of recently accepted papers

Optical polarimetry toward the Pipe nebula: revealing the importance of the magnetic field

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Magnetic fields are proposed to play an important role in the formation and support of self-gravitating clouds and the formation and evolution of protostars in such clouds. We use R-band linear polarimetry collected for about 12000 stars in 46 fields with lines of sight toward the Pipe nebula to investigate the properties of the polarization across this dark cloud complex. Mean polarization vectors show that the magnetic field is locally perpendicular to the large filamentary structure of the Pipe nebula (the 'stem'), indicating that the global collapse may have been driven by ambipolar diffusion. The polarization properties clearly change along the Pipe nebula. The northwestern end of the nebula (B59 region) is found to have a low degree of polarization and high dispersion in polarization position angle, while at the other extreme of the cloud (the 'bowl') we found mean degrees of polarization as high as ≈15% and a low dispersion in polarization position angle. The plane of the sky magnetic field strength was estimated to vary from about 17 μG in the B59 region to about 65 μG in the bowl. We propose that three distinct regions exist, which may be related to different evolutionary stages of the cloud; this idea is supported by both the polarization properties across the Pipe and the estimated mass-to-flux ratio that varies between approximately super-critical toward the B59 region and sub-critical inside the bowl. The three regions that we identify are: the B59 region, which is currently forming stars; the stem, which appears to be at an earlier stage of star formation where material has been through a collapsing phase but not yet given birth to stars; and the bowl, which represents the earliest stage of the cloud in which the collapsing phase and cloud fragmentation has already started.

Accepted by Astronomy & Astrophysics Letters

http://arxiv.org/abs/0806.1189

Evidence for a Turnover in the Initial Mass Function of Low–Mass Stars and Substellar Objects: Analysis from an Ensemble of Young Clusters

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We present a combined analysis of the low-mass initial mass function (IMF) for seven star-forming regions. We first demonstrate that the ratios of stars to brown dwarfs are consistent with a single underlying IMF. By assuming that the underlying IMF is the same for all seven clusters and by combining the ratio of stars to brown dwarfs from each cluster we constrain the shape of the brown dwarf IMF and find it to be consistent with a lognormal IMF . This provides the strongest constraint yet that the substellar IMF turns over ($\frac{dN}{dM} \propto M^{-\alpha}$, $\alpha < 0$)

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Photoevaporation of Protoplanetary Disks

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We present HST/NICMOS Paschen α (Paα) images and low and high resolution IRS spectra of photoevaporating disk-tail systems originally detected at 24μm near O stars. We find no Paα emission in any of the systems. The resulting upper limits correspond to about $2-3 \times 10^{-6}$ $M_\odot$ of mass in hydrogen in the tails suggesting that the gas is severely depleted. The IRAC data and the low resolution 5−12 μm IRS spectra provide evidence for an inner disk while high resolution long wavelength (14−30 μm) IRS spe ctra confirm the presence of a gas free "tail" that consists of ~ 0.01 t o ~ 1 μm dust grains originating in the outer parts of the circumstella r disks. Overall our observations support theoretical predictions in which photo evaporation removes the gas relatively quickly ($\leq 10^5$ yrs) from the outer region of a protoplanetary disk but leaves an inner more robust and possibly gas -rich disk component of radius 5-10 AU. With the gas gone, larger solid bodies i n the outer disk can experience a high rate of collisions and produce elevated a mounts of dust. This dust is being stripped from the system by the photon pressu re of the O star to form a gas-free dusty tail.

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Nonlinear Evolution of Gravitational Fragmentation Regulated by Magnetic Fields and Ambipolar Diffusion

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We present results from an extensive set of simulations of gravitational fragmentation in the presence of magnetic fields and ambipolar diffusion. The thin-sheet approximation is employed, with an ambient magnetic field that is oriented perpendicular to the plane of the sheet. Nonlinear development of fragmentation instability leads to substantial irregular structure and distributions of fragment spacings, fragment masses, shapes, and velocity patterns in model clouds. We study the effect of dimensionless free parameters that characterize the initial mass-to-flux ratio, neutral-ion coupling, and external pressure associated with the sheet. The average fragmentation spacing in the nonlinear phase of evolution is in excellent agreement with the prediction of linear perturbation theory. Both significantly subcritical *and* highly supercritical clouds have average fragmentation scales $\langle\lambda\rangle \approx 2\pi Z_0$, where Z_0 is the initial half-thickness of the sheet. In contrast, the qualitatively unique transcritical modes can have $\langle\lambda\rangle$ that is at least several times larger. Conversely, fragmentation dominated by external pressure can yield dense cluster formation with much smaller values of $\langle\lambda\rangle$. The time scale for nonlinear growth and runaway collapse of the first core is ≈ 10 times the calculated growth time $\tau_{\rm g,m}$ of the eigenmode with minimum growth time, when starting from a uniform background state with small-amplitude white-noise perturbations. Subcritical and transcritical models typically evolve on a significantly longer time scale than the supercritical models. Infall motions in the nonlinear fully-developed contracting cores are subsonic on the core scale in subcritical and transcritical clouds, but are somewhat supersonic in supercritical clouds. Core mass distributions are sharply peaked with a steep decline to large masses, consistent with the existence of a preferred mass scale for each unique set of dimensionless free parameters. However, a sum total of results for various initial mass-to-flux ratios yields a broad distribution reminiscent of observed core mass distributions. Core shapes are mostly near-circular in the plane of the sheet for subcritical clouds, but become progressively more elongated for clouds with

increasing initial mass-to-flux ratio. Field lines above the cloud midplane remain closest to vertical in the ambipolar-drift driven core formation in subcritical clouds, and there is increasing amount of magnetic field curvature for clouds of increasing mass-to-flux ratio. Based on our results, we conclude that fragmentation spacings, magnitude of infall motions, core shapes, and, especially, the curvature of magnetic field morphology, may serve as indirect observational means of determining a cloud's ambient mass-to-flux ratio.

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`http://www.astro.uwo.ca/~basu/pb.htm`

Evidence for primordial mass segregation in globular clusters

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We have studied the dissolution of initially mass segregated and unsegregated star clusters due to two-body relaxation in external tidal fields, using Aarseth's collisional N-body code NBODY4 on GRAPE6 special-purpose computers. When extrapolating results of initially not mass segregated models to globular clusters, we obtain a correlation between the time until destruction and the slope of the mass function, in the sense that globular clusters which are closer to dissolution are more strongly depleted in low-mass stars. This correlation fits observed mass functions of most globular clusters. The mass functions of several globular clusters are however more strongly depleted in low-mass stars than suggested by these models. Such strongly depleted mass functions can be explained if globular clusters started initially mass segregated. Primordial mass segregation also explains the correlation between the slope of the stellar mass function and the cluster concentration which was recently discovered by De Marchi et al. (2007). In this case, it is possible that all globular clusters started with a mass function similar to that seen in young open clusters in the present-day universe, at least for stars below m=0.8 Msun. This argues for a near universality of the mass function for different star formation environments and metallicities in the range -2 ¡ [Fe/H] ¡ 0. We finally describe a novel algorithm which can initialise stationary mass segregated clusters with arbitrary density profile and amount of mass segregation.

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An interferometric study of the low-mass protostar IRAS 16293-2422: small scale organic chemistry

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Aims: To investigate the chemical relations between complex organics based on their spatial distributions and excitation conditions in the low-mass young stellar objects IRAS 16293-2422 "A" and "B".
Methods: Interferometric observations with the Submillimeter Array have been performed at 5 arcsec $\times$3 arcsec (800$\times$500 AU) resolution revealing emission lines of HNCO, CH_3CN, CH_2CO, CH_3CHO and C_2H_5OH. Rotational temperatures are determined from rotational diagrams when a sufficient number of lines are detected.
Results: Compact emission is detected for all species studied here. For HNCO and CH_3CN it mostly arises from source "A", CH_2CO and C_2H_5OH have comparable strength for both sources and CH_3CHO arises exclusively from source "B". HNCO, CH_3CN and CH_3CHO have rotational temperatures >200 K implying that they arise from hot gas. The (u, v)-visibility data reveal that HNCO also has extended cold emission, which could not be previously determined through single dish data.

Conclusions: The relative abundances of the molecules studied here are very similar within factors of a few to those found in high-mass YSOs. This illustrates that the chemistry between high- and low-mass objects appears to be relatively similar and thus independent of luminosity and cloud mass. In contrast, bigger abundance differences are seen between the "A" and "B" source. For instance, the HNCO abundance relative to CH_3OH is ∼4 times higher toward "A", which may be due to a higher initial OCN^- ice abundances in source "A" compared to "B". Furthermore, not all oxygen-bearing species are co-existent, with CH_3CHO/CH_3OH an order of magnitude higher toward "B" than "A". The different spatial behavior of CH_2CO and C_2H_5OH compared with CH_3CHO suggests that successive hydrogenation reactions on grain-surfaces are not sufficient to explain the observed gas phase abundance of the latter. Selective destruction of CH_3CHO may result in the anti-coincidence of these species in source "A". These results illustrate the power of interferometric compared with single dish data in terms of testing chemical models.

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Planetesimal formation around the snow line in MRI-driven turbulent protoplanetary disks

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The formation of planetesimals in protoplanetary disks due to collisional sticking of smaller dust aggregates has to face at least two severe obstacles, namely the rapid loss of material due to radial inward drift and particle fragmentation due to destructive collisions. In this Letter we present a scenario to circumvent these two hurdles. Our dust evolution model involves two main mechanisms. First, we consider a disk with a dead zone. In a nearly laminar region around the midplane, relative turbulent particle velocities are comparatively small decreasing the probability for destructive particle collisions. Second, turbulence is not the only source for violent relative particle velocities, because high radial drift speeds can also lead to boulder fragmentation. For this reason, we additionally focus on the snow line. Evaporation fronts can be associated with gas pressure maxima in which radial drift basically vanishes. This means that particle fragmentation becomes even less likely. Our simulation results suggest that particles can overcome the fragmentation barrier. We find that boulders of several 100 m can form within only a few thousand years.

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Characterizing the velocity field in hydrodynamical simulations of low-mass star formation using spectral line profiles

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When low-mass stars form, the collapsing cloud of gas and dust goes through several stages which are usually characterized by the shape of their spectral energy distributions. Such classification is based on the cloud morphology only and does not address the dynamical state of the object. In this paper we investigate the initial cloud collapse and subsequent disk formation through the dynamical behavior as reflected in the sub-millimeter spectral emission line profiles. If a young stellar object is to be characterized by its dynamical structure it is important to know how accurately information about the velocity field can be extracted and which observables provide the best description of the kinematics. Of particular interest is the transition from infalling envelope to rotating disk, because this provides the initial conditions for the protoplanetary disk, such as mass and size. We use a hydrodynamical model, describing the collapse of a core and formation of a disk, to produce synthetic observables which we compare to calculated line profiles of a simple parameterized model. Because we know the velocity field from the hydrodynamical simulation we can determine in a quantitative way how well our best-fit parameterized velocity field reproduces the original. We use a molecular line excitation and radiation transfer code to produce spectra of both our hydro dynamical simulation as well as our parameterized model. We find that information about the velocity field can reasonably well be derived by fitting a simple model to either single-dish lines or interferometric data, but preferentially by using a combination of the two. Our result shows that it is possible to establish relative ages of a sample of young stellar objects using this method, independently of the details of the hydrodynamical model.

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Time-dependent CO depletion during the formation of protoplanetary disks

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Understanding the gas abundance distribution is essential when tracing star formation using molecular line observations. Changing density and temperature conditions cause gas to freeze-out onto dust grains, and this needs to be taken into account when modeling a collapsing molecular cloud. This study aims to provide a realistic estimate of the CO abundance distribution throughout the collapse of a molecular cloud. We provide abundance profiles and synthetic spectral lines which can be compared to observations. We use a 2D hydrodynamical simulation of a collapsing cloud and subsequent formation of a protoplanetary disk as input for the chemical calculations. From the resulting abundances, synthetic spectra are calculated using a molecular excitation and radiation transfer code. We compare three different methods to calculate the abundance of CO. Our models also consider cosmic ray desorption and the effects of an increased CO binding energy. The resulting abundance profiles are compared to observations from the literature and are found to agree well. The resulting abundance profiles agree well with analytic approximations, and the corresponding line fluxes match observational data. Our developed method to calculate abundances in hydrodynamical simulations should greatly aid in comparing these to observations, and can easily be generalized to include gas-phase reaction networks.

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Centimeter Imaging of the R Coronae Australis Region

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The R CrA region was observed in the 3.5 and 6.2 cm continuum with high angular resolutions (0.6–1.7 arcseconds) using the Very Large Array. Archival data sets were also analyzed for comparison, which provided angular resolutions up to 0.3 arcseconds. A cluster of young stellar objects was detected, and a rich array of star forming activities was revealed. IRS 7A showed an enhanced outflow activity recently. The main peak of IRS 7A positionally coincides with an X-ray source, which suggests that the X-ray emission is directly related to the central protostar. The Class 0 source SMA 2 is associated with a double radio source, B 9a and 9b, and seems to be driving two outflows. The B 9 complex is probably a multiple-protostar system. Both B 9a and 9b are nonthermal radio sources with negative spectral indices. IRS 7B is a compact radio source surrounded by an extended structure. The compact source corresponds to the Class 0/I source SMA 1, and it is also closely associated with an X-ray source, suggesting that magnetic activities start early in the protostellar stage of evolution. The extended structure of IRS 7B may be a bipolar outflow. IRS 5 was resolved into two sources with a separation of 0.9 arcseconds. Both IRS 5a and 5b display radio flares and X-ray emission, suggesting that energetic magnetic processes are active in both members. The month-scale active phase of IRS 5b implies that the flare activity must involve large-scale magnetic fields. During the strong flare event of IRS 5b in 1998, IRS 5a also showed an enhanced level of radio emission. This concurrent activity suggests that IRS 5 may be an interacting young binary system, but the interaction mechanism is unknown. Alternatively, what was seen in

the radio images could be a circumbinary halo. The variable radio source B 5 was found to be a nonthermal source at times, and the size of the 6.2 cm source is about 1 arcsecond, suggesting that B 5 is a Galactic object. A radio outburst of IRS 6 was detected once, and the radio/X-ray source was identified as IRS 6a. The other member of the IRS 6 system, IRS 6b, was undetected in X-rays, suggesting that only IRS 6a has detectable magnetic activities. Properties of other radio sources, IRS 1, IRS 2, and R CrA, are discussed, and the radio detections of T CrA and WMB 55 are reported. The proper motion of R CrA was marginally detected. Also presented is the classification of infrared sources in the R CrA region based on an infrared color-color diagram.

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http://minho.kasi.re.kr/Publications.html
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A Spitzer Study of Debris Disks In The Young Nearby Cluster NGC 2232: Icy Planets Are Common Around $\sim$ 1.5–3 $M_\odot$ Stars

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We describe Spitzer IRAC and MIPS observations of the nearby 25 Myr-old open cluster NGC 2232. Combining these data with ROSAT All-Sky Survey observations, proper motions, and optical photometry/spectroscopy, we construct a list of highly probable cluster members. We identify 1 A-type star, HD 45435, with definite excess emission at 4.5–24 μm indicative of debris from terrestrial planet formation. We also identify 2–4 late-type stars with possible 8 μm excesses, and 8 early-type stars with definite 24 μm excesses. Constraints on the dust luminosity and temperature suggest that the detected excesses are produced by debris disks. From our sample of B and A stars, stellar rotation appears correlated with 24 μm excess, a result expected if massive primordial disks evolve into massive debris disks. To explore the evolution of the frequency and magnitude of debris around A-type stars, we combine our results with data for other young clusters. The frequency of debris disks around A-type stars appears to increase from $\sim$ 25% at 5 Myr to $\sim$ 50–60% at 20–25 Myr. Older A-type stars have smaller debris disk frequencies: $\sim$ 20% at 50–100 Myr. For these ages, the typical level of debris emission rises from 5–20 Myr and then declines. Because 24 μm dust emission probes icy planet formation around A-type stars, our results suggest that the frequency of icy planet formation is $\eta_i \gtrsim$ 0.5–0.6. Thus, most A-type stars ($\approx$ 1.5–3 $M_\odot$) produce icy planets.

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Evolution of Migrating Planets Undergoing Gas Accretion

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We analyze the orbital and mass evolution of planets that undergo run-away gas accretion by means of two- and three-dimensional hydrodynamic simulations. The disk torque distribution per unit disk mass as a function of radius provides an important diagnostic for the nature of the disk-planet interactions. We first consider torque distributions for nonmigrating planets of fixed mass and show that there is general agreement with the expectations of resonance theory. We then present results of simulations for mass-gaining, migrating planets. For planets with an initial mass of 5 Earth masses ($M_{\rm E}$), which are embedded in disks with standard parameters and which undergo run-away gas accretion to one Jupiter mass ($M_{\rm J}$), the torque distributions per unit disk mass are largely unaffected by migration and accretion for a given planet mass. The migration rates for these planets are in agreement with the predictions of the standard theory for planet migration (Type I and Type II migration). The planet mass growth occurs through gas capture within the planet's Bondi radius at lower planet masses, the Hill radius at intermediate planet masses, and through reduced accretion at higher planet masses due to gap formation. During run-away mass growth, a planet migrates inwards by only about 20% in radius before achieving a mass of $\sim 1\,M_{\rm J}$. For the above models, we find no

evidence of fast migration driven by coorbital torques, known as Type III migration. We do find evidence of Type III migration for a fixed mass planet of Saturn's mass that is immersed in a cold and massive disk. In this case the planet migration is assumed to begin before gap formation completes. The migration is understood through a model in which the torque is due to an asymmetry in density between trapped gas on the leading side of the planet and ambient gas on the trailing side of the planet.

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The ISM in spiral galaxies: can cooling in spiral shocks produce molecular clouds?

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We investigate the thermodynamics of the interstellar medium (ISM) and the formation of molecular hydrogen through numerical simulations of spiral galaxies. The model follows the chemical, thermal and dynamical response of the disc to an external spiral potential. Self-gravity and magnetic fields are not included. The calculations demonstrate that gas can cool rapidly when subject to a spiral shock. Molecular clouds in the spiral arms arise through a combination of compression of the ISM by the spiral shock and orbit crowding. These results highlight that local self-gravity is not required to form molecular clouds. Self-shielding provides a sharp transition density, below whic h gas is essentially atomic, and above which the molecular gas fraction is > 0.001. The timescale for gas to move between these regimes is very rapid ($\leq$1 Myr). From this stage, the majority of gas generally takes between 10 to 20 Myr to obtain high H_2 fractions (> 50 percent). These are however strict upper limits to the H_2 formation timescale, since our calculations are unable to resolve turbulent motions on scales smaller than the spiral arm, and do not include self-gravity. True cloud formation timescales are therefore expected to be even shorter.

The mass budget of the disc is dominated by cold gas residing in the spiral arms. Between 50 and 75 percent of this gas is in the atomic phase. When this gas leaves the spiral arm and drops below the self-shielding limit it is heated by the galactic radiation field. Consequently, most of the volume in the interarm regions is filled with warm atomic gas. However, some cold spurs and clumps can survive in interarm regions for periods comparable to the interarm passage timescale. Altogether between 7 and 40 percent of the gas in our disc is molecular, depending on the surface density of the calculation, with approximately 20% molecular for a surface density comparable to the solar neighbourhood.

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Size-sorting dust grains in the surface layers of protoplanetary disks

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Context: The shape of dust emission features measured from protoplanetary disks contains information about the typical size of the dust particles residing in these disks. A flattened 10 μm silicate feature is often interpreted as proof that grain growth has taken place, while a pointy feature is taken as evidence for the pristine nature of the dust.
Aims: We wish to investigate what the effect of dust sedimentation is on the observed 10 μm feature and how this may affect the interpretation of the observations.
Methods: Using a combination of modeling tools, we simulated the sedimentation of a dust grain size distribution in an axisymmetric 2-D model of a turbulent protoplanetary disk, and we used a radiative transfer program to compute the resulting spectra.
Results: We find that the sedimentation can turn a flat feature into a pointy one, but only to a limited degree and for a very limited set of particle size distributions. If the distribution is too strongly dominated by small grains,

then the feature is pointy even before sedimentation. If the distribution is too strongly dominated by big grains, the sedimentation will not be enough to cause the feature to be pointy. Only if we have a bimodal size distribution, i.e. a very small grain population and a bigger grain population, do we find that the transformation from a flat to a pointy feature upon dust sedimentation is strong. However, our model shows that, if sedimentation is the sole reason for the variety of silicate feature strengths observed in protoplanetary disks, then we would expect to find a correlation such that disks with weak mid- to far-infrared excess have a stronger 10 μm silicate feature than disks with a strong mid- to far-infrared excess. If this is contrary to what is observed, then this would indicate that sedimentation cannot be the main reason for the variety of 10 μm silicate features observed in protoplanetary disks.

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Identifying the Low Luminosity Population of Embedded Protostars in the c2d Observations of Clouds and Cores

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We present the results of a search for all embedded protostars with internal luminosities ≤ 1.0 L$_\odot$ in the full sample of nearby, low-mass star-forming regions surveyed by the *Spitzer Space Telescope* Legacy Project "From Molecular Cores to Planet Forming Disks" (c2d). The internal luminosity of a source, L_{int}, is the luminosity of the central source and excludes luminosity arising from external heating. On average, the *Spitzer* c2d data are sensitive to embedded protostars with $L_{int} \geq 4 \times 10^{-3}$ $(d/140\,\mathrm{pc})^2$ L$_\odot$, a factor of 25 better than the sensitivity of the *Infrared Astronomical Satellite (IRAS)* to such objects. We present a set of selection criteria used to identify candidates from the *Spitzer* data and examine complementary data to decide whether each candidate is truly an embedded protostar. We find a tight correlation between the 70 μm flux and internal luminosity of a protostar, an empirical result based on both observations and detailed two-dimensional radiative transfer models of protostars. We identify 50 embedded protostars with $L_{int} \leq 1.0$ L$_\odot$; 15 have $L_{int} \leq 0.1$ L$_\odot$. The intrinsic distribution of source luminosities increases to lower luminosities. While we find sources down to the above sensitivity limit, indicating that the distribution may extend to luminosities lower than probed by these observations, we are able to rule out a continued rise in the distribution below $L_{int} = 0.1$ L$_\odot$. Between $75 - 85\%$ of cores classified as starless prior to being observed by *Spitzer* remain starless to our luminosity sensitivity; the remaining $15 - 25\%$ harbor low-luminosity, embedded protostars. We compile complete Spectral Energy Distributions for all 50 objects and calculate standard evolutionary signatures (L_{bol}, T_{bol}, and L_{bol}/L_{smm}), and argue that these objects are inconsistent with the simplest picture of star formation wherein mass accretes from the core onto the protostar at a constant rate.

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Confirmation of a gapped primordial disk around LkCa 15

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Recently, analysis of near-infrared broad-band photometry and *Spitzer* IRS spectra has led to the identification of a new "pre-transitional disk" class whose members have an inner optically thick disk separated from an outer optically thick disk by an optically thin gap. This is in contrast to the "transitional disks" which have inner disk holes (i.e. large reductions of small dust from the star out to an outer optically thick wall). In LkCa 15, one of these proposed pre-transitional disks, detailed modeling showed that although the near-infrared fluxes could be understood in terms of optically thick material at the dust sublimation radius, an alternative model of emission from optically thin dust over a wide range of radii could explain the observations as well. To unveil the true nature of LkCa 15's inner disk we obtained a medium-resolution near-infrared spectrum spanning the wavelength range 2-5 μm using SpeX at the NASA Infrared Telescope Facility. We report that the excess near-infrared emission above the photosphere of LkCa 15 is a black-body continuum which can only be due to optically thick material in an inner disk around the star. When this confirmation of a primordial inner disk is combined with earlier observations of an inner edge to LkCa 15's outer disk it reveals a gapped structure. Forming planets emerge as the most likely mechanism for clearing the gap we detect in this evolving disk.

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Redshifted Absorption at He I λ10830 as a Probe of the Accretion Geometry of T Tauri Stars

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We probe the geometry of magnetospheric accretion in classical T Tauri stars by modeling red absorption at He I λ10830 via scattering of the stellar and veiling continua. Under the assumptions that the accretion flow is an azimuthally symmetric dipole and helium is sufficiently optically thick that all incident 1-μm radiation is scattered, we illustrate the sensitivity of He I λ10830 red absorption to both the size of the magnetosphere and the filling factor of the hot accretion shock. We compare model profiles to those observed in 21 CTTS with subcontinuum redshifted absorption at He I λ10830 and find that about half of the stars have red absorptions and 1-μm veilings that are consistent with dipole flows of moderate width with accretion shock filling factors matching the size of the magnetospheric footpoints. However, the remaining 50% of the profiles, with a combination of broad, deep absorption and low 1-μm veiling, require very wide flows where magnetic footpoints are distributed over 10–20% of the stellar surface but accretion shock filling factors are $< 1\%$. We model these profiles by invoking large magnetospheres dilutely filled with accreting gas, leaving the disk over a range of radii in many narrow "streamlets" that fill only a small fraction of the entire infall region. In some cases accreting streamlets need to originate in the disk between several R_* and at least the corotation radius. A few stars have such deep absorption at velocities $> 0.5\ V_{\rm esc}$ that flows near the star with less curvature than a dipole trajectory seem to be required.

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New M dwarf debris disk candidates in NGC 2547

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With only six known examples, M-dwarf debris disks are rare, even though M dwarfs constitute the majority of stars in the Galaxy. After finding a new M dwarf debris disk in a shallow mid-infrared observation of NGC 2547, we present a considerably deeper *Spitzer*-MIPS image of the region, with a maximum exposure time of 15 minutes per pixel. Among sources selected from a previously published membership list, we identify nine new M dwarfs with excess emission at 24 μm tracing warm material close to the snow line of these stars, at orbital radii of less than 1 AU. We argue that these are likely debris disks, suggesting that planet formation is under way in these systems. Interestingly, the estimated excess fraction of M stars appears to be higher than that of G and K stars in our sample.

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The star formation in the L1615/L1616 cometary cloud

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The present work aims at performing a comprehensive census and characterisation of the pre-main sequence (PMS) population in the cometary cloud L1615/L1616, in order to assess the significance of the triggered star formation scenario and investigate the impact of massive stars on its star formation history and mass spectrum. Our study is based on $UBVR_CI_C$ and $JHKs$ photometry, as well as optical multi-object spectroscopy. We performed a physical parametrisation of the young stellar population in L1615/L1616. We identified 25 new T Tauri stars mainly projected on the dense head of the cometary cloud, almost doubling the current number of known members. We studied the spatial distribution of the cloud members as a function of the age and Hα emission. The star formation efficiency in the cloud is $\sim$ 7–8 %, as expected for molecular clouds in the vicinity of OB associations. The slope of the initial mass function (IMF), in the mass range $0.1 \le M \le 5.5\ M_{\odot}$, is consistent with that of other T and OB associations, providing further support of an universal IMF down to the hydrogen burning limit, regardless of environmental conditions. The cometary appearance, as well as the high star formation efficiency, can be explained in terms of triggered star formation induced by the strong UV radiation from OB stars or supernovae shockwaves. The age spread as well as both the spatial and age distribution of the PMS objects provide strong evidence of sequential, multiple events and possibly still ongoing star formation activity in the cloud.

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IR diagnostics of embedded jets: velocity resolved observations of the HH34 and HH1 jets

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Context. We present VLT-ISAAC medium resolution spectroscopy of the HH34 and HH1 jets, driven by young Class 0/I sources.
Aims. Our aim is to derive the kinematics and the physical parameters associated with infrared jets, and to study how they vary with jet velocity.
Methods. We use several important diagnostic lines covered by our spectral range, such as [Fe II] 1.644 μm, 1.600 μm and H_2 2.122 μm, to probe both the atomic and the molecular jet components.

Results. In the inner jet region of HH34, we find that both the atomic and molecular gas present two components at high and low velocity (the so-called HVC and LVC), as reported by previous studies. The [Fe II] LVC in HH34 is detected up to large distances from the source (> 1000 AU), at variance with TTauri jets where the LVC is usually confined within 200 AU from the star. In H_2 2.122 μm, the LVC and HVC are spatially separated, with an abrupt transition from low- to high-velocity emission at ∼1. 5". We moreover detect, for the first time, the fainter red-shifted counterpart down to the central source. This lobe shows several emission knots displaced symmetrically with respect to the corresponding blue-shifted gas. In HH1, we trace the jet down to ∼1" from the VLA1 driving source: the kinematics of this inner region is again characterised by the presence of two velocity components, one blue-shifted and one red-shifted with respect to the source LSR velocity. We interpret this double component as arising from the interaction of two different jets. We suggest that the red-shifted component could be part of the HH501 jet. Electron densities and mass fluxes have been measured separately for the different velocity components in the HH34 and HH1 jets. In the inner HH34 jet region, n_e increases with decreasing velocity, with an average value of $\sim 1 \times 10^4 cm^{-3}$ in the HVC and $\sim 2.2 \times 10^4 cm^{-3}$ in the LVC. Up to ∼ 10" from the driving source, and along the whole HH1 jet an opposite behaviour is observed instead, with n_e increasing with velocity. In both jets the mass flux is carried mainly by the high-velocity gas: lower limits on the mass flux of $3 - 8 \times 10^{-8} M_{\odot} yr^{-1}$ have been found for HH34 and HH1, from the luminosity of the [Fe II] 1.644 μm line. A comparison between the position velocity diagrams and derived electron densities with models for magnetohydrodynamic (MHD) jet launching mechanisms has been performed for HH34. While the kinematical characteristics of the line emission at the jet base can be, at least qualitatively, reproduced by both X-winds and disc-wind models, none of these models can explain the extent of the LVC and the velocity dependence of electron density that we observe. It is possible that the LVC in HH34 represents gas not directly ejected in the jet but instead denser ambient gas entrained by the high-velocity collimated jet.

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http://www.aanda.org/index.php?option=forthcoming&Itemid=18#section_5

X-ray flares in Orion young stars. I. Flare characteristics

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Pre-main sequence (PMS) stars are known to produce powerful X-ray flares which resemble magnetic reconnection solar flares scaled by factors up to 10^4. However, numerous puzzles are present including the structure of X-ray emitting coronae and magnetospheres, effects of protoplanetary disks, and effects of stellar rotation. To investigate these issues in detail, we examine 216 of the brightest flares from 161 PMS stars observed in the Chandra Orion Ultradeep Project (COUP). These constitute the largest homogeneous dataset of PMS, or indeed stellar flares at any stellar age, ever acquired. Our effort is based on a new flare spectral analysis technique that avoids nonlinear parametric modeling. It can be applied to much weaker flares and is more sensitive than standard methods. We provide a catalog with > 30 derived flare properties and an electronic atlas for this unique collection of stellar X-ray flares. The current study (Paper I) examines the flare morphologies, and provides general comparison of COUP flare characteristics with those of other active X-ray stars and the Sun. Paper II will concentrate on relationships between flare behavior, protoplanetary disks, and other stellar properties.

Several results are obtained. First, the COUP flares studied here are among the most powerful, longest, and hottest stellar X-ray flares ever studied. Second, no significant statistical differences in peak flare luminosity or temperature distributions are found among different morphological flare classes, suggesting a common underlying mechanism for all flares. Third, comparison with the general solar-scaling laws indicates that COUP flares may not fit adequately proposed power-temperature and duration-temperature solar-stellar fits. Fourth, COUP super-hot flares are found to be brighter but shorter than cooler COUP flares. Fifth, the majority of bright COUP flares can be viewed as enhanced analogs of the rare solar "long-duration events".

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X-Ray flares in Orion Young Stars. II. Flares, Magnetospheres, and Protoplanetary Disks

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We study the properties of powerful X-ray flares from 161 pre-main sequence (PMS) stars observed with the Chandra X-ray Observatory in the Orion Nebula region. Relationships between flare properties, protoplanetary disks and accretion are examined in detail to test models of star-disk interactions at the inner edge of the accretion disks. Previous studies had found no differences in flaring between diskfree and accreting systems other than a small overall diminution of X-ray luminosity in accreting systems.

Our most important finding is that X-ray coronal extents in fast-rotating diskfree stars can significantly exceed the Keplerian corotation radius, whereas X-ray loop sizes in disky and accreting systems do not exceed the corotation radius. This is consistent with models of star-disk magnetic interaction where the inner disk truncates and confines the PMS stellar magnetosphere.

We also find two differences between flares in accreting and diskfree PMS stars. First, a subclass of super-hot flares with peak plasma temperatures exceeding 100 MK are preferentially present in accreting systems. Second, we tentatively find that accreting stars produce flares with shorter durations. Both results may be consequences of the distortion and destabilization of the stellar magnetosphere by the interacting disk. Finally, we find no evidence that any flare types, even slow-rise flat-top flares are produced in star-disk magnetic loops. All are consistent with enhanced solar long-duration events with both footprints anchored in the stellar surface.

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Star Formation Near Photodissociation Regions: Detection of a Peculiar Protostar Near Ced 201

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We present the detection and characterization of a peculiar low–mass protostar (IRAS 22129+7000) located ∼0.4 pc from Cederblad 201 Photodissociation Region (PDR) and ∼0.2 pc from the HH450 jet. The cold circumstellar envelope surrounding the object has been mapped through its 1.2 mm dust continuum emission with *IRAM–30m*/MAMBO. The deeply embedded protostar is clearly detected with *Spitzer*/MIPS (70 μm), IRS (20–35 μm) and IRAC (4.5, 5.8, and 8 μm) but also in the K_s band (2.15 μm). Given the large *near– and mid–IR excess* in its spectral energy distribution, but large submillimeter-to-bolometric luminosity ratio (≃2%), IRAS 22129+7000 must be a transition Class 0/I source and/or a multiple stellar system. Targeted observations of several molecular lines from CO, ^{13}CO, C^{18}O, HCO^{+} and DCO^{+} have been obtained. The presence of a collimated molecular outflow mapped with the *CSO* telescope in the CO J=3–2 line suggests that the protostar/disk system is still accreting material from its natal envelope. Indeed, optically thick line profiles from high density tracers such as HCO^{+} J=1–0 show a red–shifted–absorption asymmetry reminiscent of inward motions. We construct a preliminary physical model of the circumstellar envelope (including radial density and temperature gradients, velocity field and turbulence) that reproduces the observed line profiles and estimates the ionization fraction. The presence of both mechanical and (non-ionizing) UV–radiative input makes the region an interesting case to study triggered star formation.

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Monitoring the Large Proper Motions of Radio Sources in the Orion BN/KL Region

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We present absolute astrometry of four radio sources in the Becklin-Neugebauer/Kleinman-Low (BN/KL) region, derived from archival data (taken in 1991, 1995, and 2000) as well as from new observations (taken in 2006). All data consist of 3.6 cm continuum emission and were taken with the Very Large Array in its highest angular resolution A configuration. We confirm the large proper motions of the BN object, the radio source I (GMR I) and the radio counterpart of the infrared source n (Orion-n), with values from 15 to 26 km s^{-1}. The three sources are receding from a point between them from where they seem to have been ejected about 500 years ago, probably via the disintegration of a multiple stellar system. We present simulations of very compact stellar groups that provide a plausible dynamical scenario for the observations. The radio source Orion-n appeared as a double in the first three epochs, but as single in 2006. We discuss this morphological change. The fourth source in the region, GMR D, shows no statistically significant proper motions. We also present new, accurate relative astrometry between BN and radio source I that restrict possible dynamical scenarios for the region. During the 2006 observations, the radio source GMR A, located about $1'$ to the NW of the BN/KL region, exhibited an increase in its flux density of a factor of $\sim$3.5 over a timescale of one hour. This rapid variability at cm wavelengths is similar to that previously found during a flare at millimeter wavelengths that took place in 2003.

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The non-dipolar magnetic fields of accreting T Tauri stars

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Models of magnetospheric accretion on to classical T Tauri stars often assume that stellar magnetic fields are simple dipoles. Recently published surface magnetograms of BP Tau and V2129 Oph have shown, however, that their fields are more complex. The magnetic field of V2129 Oph was found to be predominantly octupolar. For BP Tau the magnetic energy was shared mainly between the dipole and octupole field components, with the dipole component being almost four times as strong as that of V2129 Oph. From the published surface maps of the photospheric magnetic fields we extrapolate the coronal fields of both stars, and compare the resulting field structures with that of a dipole. We consider different models where the disc is truncated at, or well-within, the Keplerian corotation radius. We find that although the structure of the surface magnetic field is particularly complex for both stars, the geometry of the larger scale field, along which accretion is occurring, is somewhat simpler. However, the larger scale field is distorted close to the star by the stronger field regions, with the net effect being that the fractional open flux through the stellar surface is less than would be expected with a dipole magnetic field model. Finally, we estimate the disc truncation radius, assuming that this occurs where the magnetic torque from the stellar magnetosphere is comparable to the viscous torque in the disc.

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A near-infrared survey of the entire R Corona Australis cloud

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To understand low- to intermediate-mass star-formation in the nearby R Cr A molecular cloud, we try to identify the stellar content that is accessible with near-infrared observations.We obtained a JHK_s band mosaic of ∼10 arcmin × 60 arcmin covering the entire R CrA molecular cloud with unprecedented sensitivity. We present a catalogue of about 3500 near-infrared sources fainter than the saturation limit $K_s \sim 10$ mag, reaching $K_s \sim 18$ mag. We analysed the extended sources by inspecting their morphology and point sources by means of colour-colour and colour-magnitude diagrams. Additionally, we compared the extinction inferred from the NIR data with the line-of-sight dust emission at 1.2 mm. Sources towards high dust emission but relatively low H-K_s show a projected mm-exces; these sources are either immediately surrounded by cold circumstellar material or, if too red to be a true foreground object, they are embedded in the front layer of the 1.2 mm emitting dust cloud. In both cases they are most likely associated with the cloud. By means of the projected mm-excess technique we find 33 new faint near-infrared sources deeply embedded in the Coronet cluster around R CrA, for which so far about 20 bright infrared stars have been known. In contrast to the Coronet region, both the northwestern dust ridge and the southeastern cloud condensation "C" appear to be devoid of associated stars detectable with our near-infrared data. Furthermore, about a dozen sources, which are spread over the entire molecular cloud region, exhibit a possible K-band excess, but only with marginal statistical significance ($< 3\sigma$), so that we do not consider the indicated K-band excess as real. Finally, while the Herbig-Haro-like objects seen on our maps are concentrated around the Coronet, we find four new nebulae also located farther down to the southeast. At the position of IRAS 18595-3712, an X-shaped bipolar nebula is resolved; its exciting star is hidden behind an edge-on disc. The deep near-infrared survey of the entire R CrA molecular cloud strengthens the evidence for the Coronet being the region where most of the young stars are found. Our results are consistent with earlier predictions that the R CrA cloud has fragmented into sub-condensations at different star-forming stages.

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Resolving a Class I Protostar Binary System with Chandra

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Using a sub-pixel event repositioning technique, we spatially resolved X-ray emission from the infrared double system IRS 5 in the R Corona Australis molecular cloud with $\sim 0.''8$ separation. As far as we know, this result - obtained from 8 Chandra archival observations between 2000 and 2005 - is the first X-ray study of individual sources in a Class I protostar binary system with a projected separation of less than 200 AU. We extracted light curves and spectra of the individual sources using a two-dimensional image fitting method. IRS 5a at the south, the source which was brighter in the near-infrared, showed three X-ray flares lasting >20 ksec, reminiscent of X-ray flares from pre-main sequence stars, while the northern source (IRS 5b) was quiescent in X-rays in all the observations except for a 2005 August 9 observation with a factor of ∼2 flux enhancement. In quiescence, these sources showed almost identical X-ray spectra, with $N_{\rm H} \sim 4\times10^{22}$ cm^{-2}, $kT \sim 2$ keV, and log $L_{\rm X} \sim 30.2-3$ erg s^{-1}. IRS 5a showed plasma at temperatures up to $kT \sim 5-6$ keV during flares, while the column density of IRS 5b increased by a factor of 2 during an observation on 2005 August 9. We discuss the evolutionary stages and variation of the X-ray activity of these sources.

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Critical Accretion Rate for Triggered Star Formation

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We have reexamined the similarity solution for a self-gravitating isothermal gas sphere and examined implication to star formation in a turbulent cloud. When parameters are adequately chosen, the similarity solution expresses an accreting isothermal gas sphere bounded by a spherical shock wave. The mass and radius of the sphere increases in proportion to the time, while the central density decreases in proportion to the inverse square of time. The similarity solution is specified by the accretion rate and the infall velocity. The accretion rate has an upper limit for a given infall velocity. When the accretion rate is below the upper limit, there exist a pair of similarity solutions for a given set of the accretion rate and infall velocity. One of them is confirmed to be unstable against a spherical perturbation. This means that the gas sphere collapses to initiate star formation only when the accretion rate is larger than the upper limit. We have also examined stability of the similarity solution against non-spherical perturbation. Non-spherical perturbations are found to be damped.

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Chemical and physical small-scale structure in a pre-stellar core

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Aims. We present a comparative study of several molecular lines and of the dust contiunuum at 1.2mm in a pre-stellar core that is embedded in the Galactic cirrus cloud MCLD123.5+24.9. Previous studies found that the core is gravitationally stable and shows signs of inward motion.
Methods. Using the Owens Valley (OVRO) and Plateau de Bure (PdB) interferometers we obtained high-angular resolution maps of the core in the carbon monosulfide CS $(2 \rightarrow 1)$ and the cyanoacetylene HC_3N $(10 \rightarrow 9)$ transitions. Together with CS $(5 \rightarrow 4)$, $C^{34}S$ $(3 \rightarrow 2)$, and bolometer data obtained with the IRAM 30 m telescope, we analyse the excitation conditions and the structural properties of the cloud.
Results. On the one hand, the new CS $(J = 2 \rightarrow 1)$ observations reveal significant substructure on a scale of about $7''$, i.e., the beam size, corresponding to about 1050 AU at an adopted distance of 150 pc. On the other hand, the interferometric observations in the HC_3N $(J = 10 \rightarrow 9)$ transition shows just one single well resolved clump in the inner part of the core. This core is well described by an intensity profile following from a centrally peaked volume density distribution. We find no evidence for depletion of CS onto dust grains. The inward motion seen in the CS $(2 \rightarrow 1)$ occurs one-sided from the middle of the filamentary cloud towards the HC_3N core.

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Simultaneous Determination of the Cosmic Ray Ionization Rate and Fractional Ionization in DR21(OH)

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We present a new method for the simultaneous calculation of the cosmic ray ionization rate, ζ_{H_2}, and the ionization fraction, χ_e, in dense molecular clouds. A simple network of chemical reactions dominant in the creation and destruction of $HCNH^+$ and HCO^+ is used in conjunction with observed pairs of rotational transitions of several molecular species in order to determine the electron abundance and the $H_3{}^+$ abundance. The cosmic ray ionization rate is then calculated by taking advantage of the fact that, in dark clouds, it governs the rate of creation of $H_3{}^+$. We apply this technique to the case of the star-forming region DR21(OH), where we successfully detected the $(J = 3 \rightarrow 2)$ and $(J = 4 \rightarrow 3)$ rotational transitions of $HCNH^+$. We also determine the C and O isotopic ratios in this source to be $^{12}C/^{13}C = 63 \pm 4$ and $^{16}O/^{18}O = 318 \pm 64$, which are in good agreement with previous measurements in other clouds. The significance of our method lies in the ability to determine $N(H_3^+)$ and χ_e directly from observations, and estimate ζ_{H_2} accordingly. Our results, $\zeta_{H_2} = 3.1 \times 10^{-18}\,s^{-1}$ and $\chi_e = 3.2 \times 10^{-8}$, are consistent with recent determinations in other objects.

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The stellar population of M17

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The stellar content of M17 has been investigated by multicolor photometry and spectroscopy. Various independent estimates yield a distance of 2.1 ± 0.2 kpc. The ratio of total-to-selective extinction is $R = 3.9$. Within a projected area of 3.6×3.7 pc, there are several thousand stars. About 74% of them show infrared excess suggesting the presence of dense circumstellar material; the excess frequency is higher for fainter stars.

The number of spectroscopically classified exciting stars could be enlarged from 13 to 46. The two central O4 stars are both spectroscopic binaries; multiplicity of other early O-type stars could also be established, increasing the number of high-mass stars even further.

Our data suggest at least two episodes of star formation: There are about 500 ZAMS sources ($2 < A_V$[mag] < 7) – among them many spectroscopically classified OB stars and a significant fraction of lower-mass sources with infrared excess ($\sim 25\%$) and X-ray emission ($\sim 6\%$). About 3350 heavily reddened sources with $10 < A_V$[mag] < 40) are most likely deeply embedded pre-main sequence objects with an age of less than 5×10^5 years. This group contains about 47% sources with infrared excess and 12% X-ray emitters. Cluster members later than about A0 have not yet reached the main sequence.

Additionally, a group of 647 protostellar candidates ($1.5 < K - L < 6.9$) has been detected in the cluster center as well as in the northern and southwestern bar. This population of accreting protostars argues in favor of ongoing star formation triggered by the central O stars in M17.

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Variations on Debris Disks: Icy Planet Formation at 30-150 AU for 1-3 Solar Mass Main Sequence Stars

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We describe calculations for the formation of icy planets and debris disks at 30–150 AU around 1–3 $M_\odot$ stars. Debris disk formation coincides with the formation of planetary systems. As protoplanets grow, they stir leftover planetesimals to large velocities. A cascade of collisions then grinds the leftovers to dust, forming an observable debris disk. Stellar lifetimes and the collisional cascade limit the growth of protoplanets. The maximum radius of icy planets, $r_{max} \approx$ 1750 km, is remarkably independent of initial disk mass, stellar mass, and stellar age. These objects contain $\lesssim$ 3%–4% of the initial mass in solid material. Collisional cascades produce debris disks with maximum luminosity $\sim 2 \times 10^{-3}$ times the stellar luminosity. The peak 24 μm excess varies from $\sim$ 1% times the stellar photospheric flux for 1 $M_\odot$ stars to $\sim$ 50 times the stellar photospheric flux for 3 $M_\odot$ stars. The peak 70–850 μm excesses are $\sim$ 30–100 times the stellar photospheric flux. For all stars, the 24–160 μm excesses rise at stellar ages of 5–20 Myr, peak at 10–50 Myr, and then decline. The decline is roughly a power law, $f \propto t^{-n}$ with $n \approx$ 0.6–1.0. This predicted evolution agrees with published observations of A-type and solar-type stars. The observed far-IR color evolution of A-type stars also matches model predictions.

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Multiplicity of young stars in and around R Corona Australis

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In star-forming regions like Taurus-Auriga, it has been found that most young stars are born as multiples, which theories for star formation should definitely take into account. The R CrA star-forming region has a small dark cloud with quite a number of protostars, T Tauri stars, and some Herbig Ae/Be stars, plus a number of weak-line T Tauri stars around the cloud found by ROSAT follow-up observations.
We searched for multiples among the young stars in and around the R CrA cloud in order to investigate multiplicity in this region.
We performed interferometric and imaging observations with the speckle camera SHARP I at the ESO 3.5 m NTT and adaptive optics observation with ADONIS at the ESO 3.6 m telescope, all in the near-infrared bands JHK obtained in the years 1995, 2000, and 2001.
We found 13 new binaries among the young stars in CrA between 0.13 arcsec (the diffraction limit) and 6 arcsec (set as an upper separation limit to avoid contamination by chance alignments). While most multiples in CrA are binaries, there are also one quadruple (TY CrA), and one triple (HR 7170) which may form a quintuple together with the binary HR 7169. One of the newly detected companions with a large magnitude difference found near the M3-5 type T Tauri star [MR 81] Hα 17 could be a brown dwarf or an infrared companion with an edge-on disk. Among seven Herbig Ae/Be stars in CrA, six are multiple.
The multiplicity frequency in CrA is as high as in similar star forming regions. By comparing with the period distribution of main-sequence stars and extrapolating to separations not probed in this survey, we conclude that the companion-star frequency is $(95 \pm 23)\,\%$; i.e. the average number of companions per primary is 0.95.

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http://www.lsw.uni-heidelberg.de/users/rkoehler/Papers/index.html,
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The origin of hydrogen line emission for five Herbig Ae/Be stars spatially resolved by VLTI/AMBER spectro-interferometry

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Context. Accretion and outflow processes are of fundamental importance for our understanding of the formation of stars and planetary systems. To trace these processes, diagnostic spectral lines such as the Brγ 2.166 μm line are widely used, although due to a lack of spatial resolution, the origin of the line emission is still unclear.
Aims. Employing the AU-scale spatial resolution which can be achieved with infrared long-baseline interferometry, we aim to distinguish between theoretical models which associate the Brγ line emission with mass infall (magnetospheric accretion, gaseous inner disks) or mass outflow processes (stellar winds, X-winds, or disk winds).
Methods. Using the VLTI/AMBER instrument, we spatially and spectrally ($\lambda/\Delta\lambda = 1500$) resolved the inner ($\lesssim$5 AU) environment of five Herbig Ae/Be stars (HD 163296, HD 104237, HD 98922, MWC 297, V921 Sco) in the Brγ emission line as well as in the adjacent continuum. From the measured wavelength-dependent visibilities, we derive the characteristic size of the continuum and Brγ line-emitting region. Additional information is provided by the closure phase, which we could measure both in the continuum wavelength regime (for four objects) as well as in the spectrally resolved Brγ emission line (for one object). The spectro-interferometric data is supplemented by archival and new VLT/ISAAC spectroscopy.
Results. For all objects (except MWC 297), we measure an increase of visibility within the Brγ emission line, indicating that the Brγ-emitting region in these objects is more compact than the dust sublimation radius. For HD 98922, our quantitative analysis reveals that the line-emitting region is compact enough to be consistent with the magnetospheric accretion scenario. For HD 163296, HD 104237, MWC 297, and V921 Sco we identify an extended stellar wind or a disk wind as the most likely line-emitting mechanism. Since the stars in our sample cover a wide range of stellar parameters, we also search for general trends and find that the size of the Brγ-emitting region does not seem to depend on the basic stellar parameters (such as the stellar luminosity), but correlates with spectroscopic properties, in particular with the Hα line profile shape.
Conclusions. By performing the first high-resolution spectro-interferometric survey on Herbig Ae/Be stars, we find evidence for at least two distinct Brγ line-formation mechanisms. Most significant, stars with a P-Cygni Hα line profile and a high mass-accretion rate seem to show particularly compact Brγ-emitting regions ($R_{\mathrm{Br}\gamma}/R_{\mathrm{cont}} < 0.2$), while stars with a double-peaked or single-peaked Hα-line profile show a significantly more extended Brγ-emitting region ($0.6 < R_{\mathrm{Br}\gamma}/R_{\mathrm{cont}} < 1.4$), possibly tracing a stellar wind or a disk wind.

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The independent estimation of the interstellar extinction in a direction of FU Ori

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Speckle-interferometric observations of the fuor FU Ori were carried out at 6-meter telescope of Special Astrophysical Observatory in the transmission bands of filters with 600/40 nm and 800/100 nm central wavelength/half width. We succeded to detect the companion of the fuor (recently discovered at wavelength $\lambda \geq 1.25$ mkm) in 800/100 nm band and found the following values of position parameters and diffrence of brightness: $\theta = 163.9^o \pm 1.0$, $\rho = 0.493'' \pm 0.007$, $\Delta m = 3.96^m \pm 0.28$. It was concluded from the analysis of companion's spectral energy distribution that the extinction A_V in the direction of the fuor can exceed 1.6^m, i.e. the minimal value which is necessary in theoretical models of the fuor, if spectral type of the companion is not later than K3. The reliability of the conclusion and the possibility of

more precise determination of A_V are discussed.

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Near-Infrared Imaging Polarimetry of M42: Aperture Polarimetry of Point-like Sources

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We have conducted aperture polarimetry of ∼500 stars of the Orion Nebula Cluster (ONC) in M42 based on our wide-field ($\sim 8' \times 8'$) $JHKs$ band polarimetry. Most of the near-infrared (NIR) polarizations are dichroic, with position angles of polarization agreeing, both globally and locally, with previous far-infrared (FIR) and submillimeter observations, having taken into account the 90° difference in angles between dichroic absorption and emission. This is consistent with the idea that both NIR dichroic polarizations and FIR/submillimeter thermal polarizations trace the magnetic fields in the OMC-1 region. The magnetic fields inferred from these observations show a pinch at scales less than 0.5 pc with a centroid near IRc2. The hourglass-shaped magnetic field pattern is explained by the models in which the magnetic field lines are dragged along with the contracting gas and then wound up by rotation in a disk. The highly polarized region to the northwest of IRc2 and the low-polarized region near the bright bar are also common among NIR and FIR/submillimeter data, although a few regions of discrepancy exist.

We have also discerned ∼50 possible highly polarized sources whose polarizations are more likely to be intrinsic rather than dichroic. Their polarization efficiencies ($P(H)/A(H)$) are too large to be explained by the interstellar polarization. These include 10 young brown dwarfs that suggest a higher polarization efficiency, which may present geometrical evidence for (unresolved) circumstellar structures around young brown dwarfs.

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SPH simulations of grain growth in protoplanetary disks

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Aims In order to understand the first stages of planet formation, when tiny grains aggregate to form planetesimals, one needs to simultaneously model grain growth, vertical settling and radial migration of dust in protoplanetary disks. In this study, we implement an analytical prescription for grain growth into a 3D two-phase hydrodynamics code to understand its effects on the dust distribution in disks.

Methods Following the analytic derivation of Stepinski & Valageas (1997), which assumes that grains stick perfectly upon collision, we implement a convenient and fast method of following grain growth in our 3D, two-phase (gas+dust) SPH code. We then follow the evolution of the size and spatial distribution of a dust population in a classical T Tauri star disk.

Results We find that the grains go through various stages of growth due to the complex interplay between gas drag, dust dynamics, and growth. Grains initially grow rapidly as they settle to the mid-plane, then experience a fast radial migration with little growth through the bulk of the disk, and finally pile-up in the inner disk where they grow more efficiently. This results in a bimodal distribution of grain sizes. Using this simple prescription of grain growth, we find that grains reach decimetric sizes in 10^5 years in the inner disk and survive the fast migration phase.

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A Multiplicity Census of Young Stars in Chamaeleon I

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We present the results of a multiplicity survey of 126 stars spanning ∼0.1–3 $M_\odot$ in the ∼2-Myr-old Chamaeleon I star-forming region, based on adaptive optics imaging with the ESO Very Large Telescope. Our observations have revealed 30 binaries and 6 triples, of which 19 and 4, respectively, are new discoveries. The overall multiplicity fraction we find for Cha I (∼30%) is similar to those reported for other dispersed young associations, but significantly higher than seen in denser clusters and the field, for comparable samples. Both the frequency and the maximum separation of Cha I binaries decline with decreasing mass, while the mass ratios approach unity; conversely, tighter pairs are more likely to be equal mass. We confirm that brown dwarf companions to stars are rare, even at young ages at wide separations. Based on follow-up spectroscopy of two low-mass substellar companion candidates, we conclude that both are likely background stars. The overall multiplicity fraction in Cha I is in rough agreement with numerical simulations of cloud collapse and fragmentation, but its observed mass dependence is less steep than predicted. The paucity of higher-order multiples, in particular, provides a stringent constraint on the simulations, and seems to indicate a low level of turbulence in the prestellar cores in Cha I.

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The Rosette Eye: the key transition phase in the birth of a massive star

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Massive protostars dramatically influence their surroundings via accretion-induced outflows and intense radiation fields. They evolve rapidly, the disk and infalling envelope being evaporated and dissipated in $\sim 10^5$ years. Consequently, they are very rare and investigating this important phase of early stellar evolution is extremely difficult. Here we present the discovery of a key transient phase in the emergence of a massive young star, in which ultraviolet radiation from the new-born giant has just punctured through its natal core. The massive young stellar object AFGL 961 II is readily resolved in the near infrared. Its morphology closely resembles a cat's eye and is here dubbed as the Rosette Eye. Emerging ionized flows blow out an hourglass shaped nebula, which, along with the existence of strong near-infrared excess, suggests the existence of an accretion disk in the perpendicular direction. The lobes of the hourglass, however, are capped with arcs of static H_2 emission produced by fluorescence. This study has strong implications for our understanding of how massive stars embark on their formation.

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Binary Formation in Star-Forming Clouds with Various Metallicities

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Cloud evolution for various metallicities is investigated by three-dimensional nested grid simulations, in which the initial ratio of rotational to gravitational energy of the host cloud β_0 ($= 10^{-1}$–10^{-6}) and cloud metallicity Z ($= 0$–$Z_\odot$) are parameters. Starting from a central number density of $n_c = 10^4\,\mathrm{cm}^{-3}$, cloud evolution for 48 models is calculated until the protostar is formed ($n_c \simeq 10^{23}\,\mathrm{cm}^{-3}$) or fragmentation occurs. The fragmentation condition depends both on the initial rotational energy and cloud metallicity. Cloud rotation promotes fragmentation, while fragmentation tends to be suppressed in clouds with higher metallicity. Fragmentation occurs when $\beta_0 > 10^{-3}$ in clouds with solar metallicity ($Z = Z_\odot$), while fragmentation occurs when $\beta_0 > 10^{-5}$ in the primordial gas cloud ($Z = 0$). Clouds with lower metallicity have larger probability of fragmentation, which indicates that the binary frequency is a decreasing function of cloud metallicity. Thus, the binary frequency at the early universe (or lower metallicity environment) is higher than at present day (or higher metallicity environment). In addition, binary stars born from low-metallicity clouds have shorter orbital periods than those from high-metallicity clouds. These trends are explained in terms of the thermal history of the collapsing cloud.

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Discovery of OH in Circumstellar Disks around Young Intermediate-Mass Stars

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We detect emission from multiple low-excitation ro-vibrational transitions of OH from the two Herbig Ae stars AB Aurigae and MWC 758 in the $3.0 - 3.7\mu$m wavelength range (L-band), using the NIRSPEC instrument on Keck II. The inner radius for the emitting region in both stars is close to 1 AU. We compare an optically thin LTE model and a thin-wedge fluorescence model, finding rotational temperatures of $650 - 800$ K and OH abundances of $10^{42} - 10^{45}$ molecules for the two stars. Comparisons with current chemical models support the fluorescence excitation model for AB Aurigae and possibly MWC 758, but further observations and detailed modeling are necessary to improve constraints on OH emission in different disk environments.

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Evolution of massive protostars: the IRAS 18151−1208 region

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Context. The study of physical and chemical properties of massive protostars is critical for better understanding the evolutionary sequence that leads to the formation of high-mass stars.
Aims. IRAS 18151−1208 is a nearby massive region ($d = 3$ kpc, $L \sim 2{\times}10^4$ L$_\odot$) that splits into three cores: MM1, MM2, and MM3 (separated by $1'$–$2'$). We aim at (1) studying the physical and chemical properties of the individual

MM1, MM2, and MM3 cores; (2) deriving their evolutionary stages; (3) using these results to improve our view of the evolutionary sequence of massive cores.
Methods. The region was observed in the CS, $C^{34}S$, H_2CO, HCO^+, $H^{13}CO^+$, and N_2H^+ lines at mm wavelengths with the IRAM 30m and Mopra telescopes. We use 1D and 2D modeling of the dust continuum to derive the density and temperature distributions, which are then used in the RATRAN code to model the lines and constrain the abundances of the observed species.
Results. All the lines were detected in MM1 and MM2. MM3 shows weaker emission, or is even undetected in HCO^+ and all isotopic species. MM2 is driving a newly discovered CO outflow and hosts a mid-IR-quiet massive protostar. The abundance of CS is significantly greater in MM1 than in MM2, but smaller than in a reference massive protostar such as AFGL 2591. In contrast, the N_2H^+ abundance decreases from MM2 to MM1, and is larger than in AFGL 2591.
Conclusions. Both MM1 and MM2 host an early-phase massive protostar, but MM2 (and mid-IR-quiet sources in general) is younger and dominated more by the host protostar than MM1 (mid-IR-bright). The MM3 core is probably in a pre-stellar phase. We find that the $N_2H^+/C^{34}S$ ratio varies systematically with age in the massive protostars for which the data are available. It can be used to identify young massive protostars.

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Extrasolar Planet Eccentricities from Scattering in the Presence of Residual Gas Disks

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Gravitational scattering between massive planets has been invoked to explain the eccentricity distribution of extrasolar planets. For scattering to occur, the planets must either form in – or migrate into – an unstable configuration. In either case, it is likely that a residual gas disk, with a mass comparable to that of the planets, will be present when scattering occurs. Using explicit hydrodynamic simulations, we study the impact of gas disks on the outcome of two-planet scattering. We assume a specific model in which the planets are driven toward instability by gravitational torques from an outer low mass disk. We find that the accretion of mass and angular momentum that occurs when a scattered planet impacts the disk can strongly influence the subsequent dynamics by reducing the number of close encounters. The eccentricity of the innermost surviving planet at the epoch when the system becomes Hill stable is not substantially altered from the gas-free case, but the outer planet is circularized by its interaction with the disk. The signature of scattering initiated by gas disk migration is thus a high fraction of low eccentricity planets at larger radii accompanying known eccentric planets. Subsequent secular evolution of the two planets in the presence of damping can further damp both eccentricities, and tends to push systems away from apsidal alignment and toward anti-alignment. We note that the late burst of accretion when the outer planet impacts the disk is in principle observable, probably via detection of a strong near-IR excess in systems with otherwise weak disk and stellar accretion signatures.

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Magnetocentrifugally Driven Flows from Young Stars and Disks. VI. Accretion with a Multipole Stellar Field

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Previous analyses of magnetospheric accretion and outflow in classical T Tauri stars (CTTSs), within the context of both the X-wind model and other theoretical scenarios, have assumed a dipolar geometry for the stellar magnetic field if it were not perturbed by the presence of an accreting, electrically conducting disk. However, CTTS surveys reveal that accretion hot spots cover a small fraction of the stellar surface, and that the net field polarization on the stellar surface is small. Both facts imply that the magnetic field generated by the star has a complex non-dipolar structure. To address this discrepancy between theory and observations, we re-examine X-wind theory without the dipole constraint. Using simple physical arguments based on the concept of trapped flux, we show that a dipole configuration is in fact not essential. Independent of the precise geometry of the stellar magnetosphere, the requirement for a certain level of trapped flux predicts a definite relationship among various CTTS observables. Moreover, superposition of multipole stellar fields naturally yield small observed hot-spot covering fractions and small net surface polarizations. The generalized X-wind picture remains viable under these conditions, with the outflow from a small annulus near the inner disk edge little affected by the modified geometry, but with inflow highly dependent on the details of how the emergent stellar flux is linked and trapped by the inner disk regions. Our model is consistent with data, including recent spectropolarimetric measurements of the hot spot sizes and field strengths in V2129 Oph and BP Tau.

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The pre-ZAMS nature of Mol160/IRAS23385+6053 confirmed by Spitzer

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The formation of massive stars goes through phases that remain heavily obscured until the object is well along on the main sequence. The identification of massive YSOs in different evolutionary phases is therefore particularly difficult, and requires a statistical approach with large samples of candidate objects to determine the observational signatures of these different phases.

A mandatory activity in this context is the identification and characterisation of all the phases that a massive forming YSO undergoes. It is of particular interest to verify the observability of the phase in which the object is rapidly accreting while not yet igniting the fusion of hydrogen that marks the arrival on the ZAMS.

One of the candidate prototypical objects for this phase is Mol160/IRAS23385+6053, which has been the subject of detailed studies that confirmed and strengthened the possibility that this massive YSO may be in a pre-hot core stage. We further investigate this issue by means of *Spitzer* imaging and spectroscopy in the 5-70 μm range.

The dense core of Mol160/IRAS23385+6053, which up to now had only been detected at submillimeter and millimeter wavelengths, with only upper limits below 20 μm, has been revealed for the first time at 24 and 70 μm by *Spitzer*. These observations confirm the earlier assumptions that this object is dominant at far-IR wavelengths. The complete 24 μm-3.4 mm continuum cannot be fitted with a standard model of a zero-age main-sequence (ZAMS) star embedded in an envelope. A simple greybody fit yields a mass of 220 $M_\odot$. The luminosity is slightly in excess of 3000 $L_\odot$, which is a factor of 5 less than previous estimates when only IRAS fluxes were available between 20 and 100 μm. The source is under-luminous by the same factor with respect to UCHII regions or hot-cores of similar circumstellar mass, and simple models show that this is compatible with an earlier evolutionary stage. Spectroscopy between 5-40 μm shows that the physical conditions are typical of a photo-dissociated or photo-ionized region. The required UV illumination can be provided by some of the other sources revealed at $\lambda \leq 24\mu$m in the same star-forming region, that can be plausibly modeled as moderately embedded intermediate-mass ZAMS stars.

Our results strengthen the suggestion that the central core in Mol160/IRAS23385+6053 is a massive YSO actively accreting from its circumstellar envelope and that it has not yet begun hydrogen fusion.

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The Local Environment of the FUor-like Objects AR 6A and 6B

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We present new ^{12}CO J=3-2 and HCN J=3-2 molecular line maps of the region surrounding the young star AR 6 using the 15 metre James Clerk Maxwell Telescope. AR 6 was previously found to be a double source with both components exhibiting several characteristics of FU Orionis (FUor) eruptive variable stars. The aims of this investigation were to determine if the AR 6 sources are associated with molecular outflows and if a significant reservoir of natal molecular gas and dust exists around the stars. These observations form part of a large-scale study of the outflow and circumstellar environment characteristics of FUors and FUor-like objects to place constrains on the age and evolutionary state of sources exhibiting FUor-like tendencies. Our data indicates that AR 6, like FU Orionis itself, does not possess a CO outflow and likewise, does not show evidence for large amounts of molecular gas in its circumstellar environment. In fact, AR 6 seems to lie in a local minimum of HCN emission. This is also found in 850 μm dust emission seen in JCMT archival data. We conclude that from the near-IR to the sub-mm, AR 6 is similar to FU Orionis in several respects. We interpret the lack of significant dust and molecular gas in the circumstellar environment of AR 6, together with the large near-IR thermal excess, as evidence that the sources have exhausted their natal envelopes, that they have at least small hot circumstellar disks, and that they are more evolved than Class I protostars. This, in itself, suggests that, since FUor eruptions have also been observed in stars with large dust mass envelopes (e.g. V346 Nor) and with CO outflows (e.g. L1551 IRS5), FUor events probably occur at many different stages in the early, formative phase of a star's life, and lends support to the idea that FUor outbursts are repetitive like their shorter-lived relatives occurring in EXor eruptive variables.

Finally, we study the stellar environment around AR 6 using 2MASS, *Spitzer* IRAC, and *Chandra* ACIS images and show that, being part of the 'Spokes' young stellar cluster, AR 6 is unlike many FUors which typically are located in more sparsely populated regions.

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Protostar Mass Due to Infall and Dispersal

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The mass of a protostar is calculated from the infall and dispersal of an isothermal sphere in a uniform background. For high contrast between peak and background densities and for short dispersal time t_d, the accretion is "self-limiting": gas beyond the core is dispersed before it accretes, and the protostar mass approaches a time-independent value of low mass. For lower density contrast and longer dispersal time, the accretion "runs away": gas accretes from beyond the core, and the protostar mass approaches massive star values. The final protostar mass is approximately the initial gas mass whose free-fall time equals t_d. This mass matches the peak of the IMF for gas temperature 10 K, peak and background densities 10^6 and 10^3 cm^{-3}, and for t_d comparable to the core free-fall time t_{core}. The accretion luminosity exceeds 1 $L_\odot$ for 0.1 Myr, as in the "Class 0" phase. For t_d/t_{core}=0.4-0.8 and temperature 7-50 K, self-limiting protostar masses are 0.08-5 $M_\odot$. These protostar and core masses have ratio 0.4 $\pm$ 0.2, as expected if the core mass distribution and the IMF have the same shape.

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Luminosity and Mass Functions at the Very Low-Mass Side in NGC 1333

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We present the results of a deep near-infrared (NIR) imaging survey searching for very low-mass young stellar objects

(YSOs) in the embedded cluster associated with the Perseus molecular cloud. Our observations cover an area of $\sim 5' \times 5'$ in the NGC 1333-S region at J, H, and Ks bands. The 10 σ limiting magnitudes exceed 18 mag in all three bands. Based on NIR color-color diagrams, embedded YSO candidates were identified using NIR excesses. The derived frequency of these YSO candidates with NIR excess emission among all the detected sources is 58^{+10}_{-13} %. The higher frequency of YSOs with NIR excesses implies that NGC 1333 is an active and young star-forming region. Approximately half of the YSO candidates exhibit extremely low luminosity, indicating very low mass. Combining the reddening-corrected luminosity with theoretical evolutionary models, the low-luminosity YSO candidates are considered to be young substellar mass objects. Furthermore, some sources could have planetary masses. In addition, we carried out CO molecular-line observations of the same cloud region. The results suggested that the YSO candidates are likely formed on the side of the parent molecular cloud and star formation activity could be high. The K-band luminosity function of all the detected sources revealed a significant population of extremely low-luminosity sources in NGC 1333. The reddening-corrected J-band luminosity function of the YSO candidates does not clearly decline to the completeness limit and seems to be bimodal. We also argue that the fraction of substellar objects is larger than those in other young clusters and the mass function of the YSO candidates appears to be increasing toward the substellar mass regime, similar to that of dust clumps. It implies that substellar mass distributions may depend on the initial conditions of the molecular cloud.

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http://harbor.scitec.kobe-u.ac.jp/ yummy/perse/n1333.pdf

High Velocity Features in the Orion Nebula

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We have used widely spaced in time Hubble Space Telescope images to determine tangential velocities of features associated with outflows from young stars. These observations were supplemented by groundbased telescope spectroscopy and from the resultant radial velocities, space velocities were determined for many outflows. Numerous new moving features were found and grouped into known and newly assigned Herbig Haro objects.

It was found that stellar outflow is highly discontinuous, as frequently is the case, with long term gaps of a few hundred years and that these outflow periods are marked by staccato bursts over periods of about ten years. Although this has been observed in other regions, the Orion Nebula Cluster presents the richest display of this property.

Most of the large scale Herbig Haro objects in the brightest part of the Orion Nebula appear to originate from a small region northeast of the strong Orion-S radio and infrared sources. With the possible exception of HH 203, we are not able to identify specific stellar sources, but do identify candidate sources for several other bright Herbig Haro objects.

We find that there are optical features in the BN-KL region that can be related to the known large scale outflow that originates there. We find additional evidence for this outflow originating 500–1000 years ago.

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Reprints are available at the anonymous ftp server orion.phy.vanderbilt.edu as outgoing/OrionHighVelocityMotions.pdf

Encounters in the ONC – observing imprints of star-disc interactions

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The external destruction of protoplanetary discs in a clustered environment acts mainly due to two mechanisms: gravitational drag by stellar encounters and evaporation by strong stellar winds and radiation. If encounters play a role in disc destruction, one would expect that stars devoid of disc material would show unexpectedly high velocities as an outcome of close interactions. We want to quantify this effect by numerical simulations and compare it to observations.

As a model cluster we chose the Orion Nebula Cluster (ONC). We found from the observational data that 8 to 18 stars leave the ONC with velocities several times the velocity dispersion. The majority of these high-velocity stars are young low-mass stars, among them several lacking infrared excess emission. Interestingly, the high-velocity stars are found only in two separate regions of the ONC. Our simulations give an explanation for the location of the high-velocity stars and provide evidence for a strong correlation between location and disc destruction. The high-velocity stars can be explained as the outcome of close three-body encounters; the partial lack of disc signatures is attributed to gravitational interaction. The spatial distribution of the high-velocity stars reflects the initial structure and dynamics of the ONC. Our approach can be generalized to study the evolution of other young dense star clusters, like the Arches cluster, back in time.

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Gas and dust mass in the disk around the Herbig Ae star HD169142

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Spatially resolved observations of circumstellar disks at millimeter wavelengths allow detailed comparison with theoretical models for the radial and vertical distribution of the material. We investigate the physical structure of the gas component of the disk around the pre-main-sequence star HD169142 and test the disk model derived from the spectral energy distribution. The ^{13}CO and C^{18}O J=2–1 line emission is observed from the disk with 1.4" resolution using the Submillimeter Array. We adopt the disk physical structure derived from a model which fits the spectral energy distribution of HD169142. We obtain the full three-dimensional information on the CO emission with the aid of a molecular excitation and radiative transfer code. This information is used for the analysis of our observations and previous ^{12}CO J=2–1 and 1.3 mm continuum data. The spatially resolved ^{13}CO and C^{18}O emission shows a Keplerian velocity pattern. The disk is seen at an inclination close to 13° from face-on. We conclude that the regions traced by different CO isotopologues are distinct in terms of their vertical location within the disk, their temperature and their column densities. With the given disk structure, we find that freeze-out is not efficient enough to remove a significant amount of CO from gas phase. Both observed lines match the model prediction both in flux and in the spatial structure of the emission. Therefore we use our data to derive the ^{13}CO and C^{18}O mass and consequently the ^{12}CO mass using standard isotopic ratios. We constrain the total disk gas mass to $(0.6\text{-}3.0)\times10^{-2}$ M$_\odot$. Adopting a maximum dust opacity of 2 cm^{2}g$^{-1}_{\rm dust}$ we derive a minimum dust mass of 2.16×10^{-4} M$_\odot$ from the fit to the 1.3 mm data. Comparison of the derived gas and dust mass shows that the gas to dust mass ratio of 100 is only possible under the assumption of a dust opacity of 2 cm^{2}g^{-1} and ^{12}CO abundance of 10^{-4} with respect to H_2. However, our data are also compatible with a gas to dust ratio of 25, with a dust opacity of 1 cm^{2}g^{-1} and ^{12}CO abundance of 2×10^{-4}.

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The Shape of the Initial Cluster Mass Function: What It Tells Us about the Local Star Formation Efficiency

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We explore how the expulsion of gas from star cluster forming cloud cores due to supernova explosions affects the shape of the initial cluster mass function, that is, the mass function of star clusters when effects of gas expulsion are over. We demonstrate that if the radii of cluster-forming gas cores are roughly constant over the core mass range, as supported by observations, then more massive cores undergo slower gas expulsion. Therefore, for a given star formation efficiency, more massive cores retain a larger fraction of stars after gas expulsion. The initial cluster mass function may thus differ from the core mass function substantially, with the final shape depending on the star formation efficiency. [Abridged]

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Line Structure in the Spectrum of FU Orionis

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New high-resolution spectra of FU Ori, obtained with the HIRES spectrograph at the Keck I telescope in 2003–2006, make it possible to compare the optical line profiles with those predicted by the self-luminous accretion disk model. A dependence of line width on excitation potential and on wavelength, expected for a Keplerian disk, is definitely not present in the optical region, nor is the line duplicity due to velocity splitting. The absorption lines observed in the optical region of FU Ori must originate in or near the central object, and here their profiles are shown to be those expected of a rigidly rotating object. They can be fitted by a rapidly rotating (v sin i = 70 km s^{-1}) high-luminosity G-type star having a large dark polar spot, with axis inclined toward the line of sight. Over these years, the radial velocity of FU Ori has remained constant to within ±0.3 km s^{-1}, so there is no indication that the star is a spectroscopic binary. These results apply to the optical region ($\lambda < 8800$ Å); more distant, cooler regions of the disk contribute in the infrared.

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Accretion bursts in young stars driven by cluster environment

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The standard picture of accretion is a steady flow of matter from the disc onto the young star - a concept which assumes the star-disc system to be completely isolated. However, in a dense cluster environment star-disc systems do interact gravitationally. The aim here is to estimate the encounter-induced accretion rate in an ONC-like environment. Combining simulations of the cluster dynamics with simulations of the effect of encounters on star-disc systems we determine the likelihood and degree of encounter-triggered accretion processes. We show that accretion bursts triggered by encounters of star-disc systems are common in young dense clusters like the ONC leading in the outburst phase to typical accretion rates of 10^{-7}-10^{-4} $M_\odot$/yr. Up to a third of stars presently in the Trapezium region accreted at least 1% of their disc mass via this mechanism in the last 1Myr. Accretion of over 6-7% of the disc material can occur in a single encounter. Despite losing their discs quickly, the total percentage of disc matter accreted per star is largest for the massive stars. Supplementing the steady accretion flow there exist episodic periods of high accretion in dense cluster environments. Due to their high accretion rate these processes should be observable even now in some of the low-mass stars in the ONC.

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Spectro-astrometric imaging of molecular gas within protoplanetary disk gaps

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We present velocity-resolved spectro-astrometric imaging of the 4.7 μm rovibrational lines of CO gas in protoplanetary disks using the CRIRES high resolution infrared spectrometer on the Very Large Telescope (VLT). The method as applied to three disks with known dust gaps or inner holes out to 4-45 AU (SR 21, HD 135344B and TW Hya) achieves an unprecedented spatial resolution of $0.1-0.5$ AU. While one possible gap formation mechanism is dynamical clearing by giant planets, other equally good explanations (stellar companions, grain growth, photo-evaporation) exist. One way of distinguishing between different scenarios is the presence and distribution of gas inside the dust gaps. Keplerian disk models are fit to the spectro-astrometric position-velocity curves to derive geometrical parameters of the molecular gas. We determine the position angles and inclinations of the inner disks with accuracies as good as 1-2°, as well as the radial extent of the gas emission. Molecular gas is detected well inside the dust gaps in all three disks. The gas emission extends to within a radius of 0.5 AU for HD 135344B and to 0.1 AU for TW Hya, supporting partial clearing by a $< 1-10\,M_{\rm Jup}$ planetary body as the cause of the observed dust gaps, or removal of the dust by extensive grain coagulation and planetesimal formation. The molecular gas emission in SR 21 appears to be truncated within ~ 7 AU, which may be caused by complete dynamical clearing by a more massive companion. We find a smaller inclination angle of the inner disk of TW Hya than that determined for the outer disk, suggestive of a disk warp. We also detect significant azimuthal asymmetries in the SR 21 and HD 135344B inner disks.

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Spitzer IRAC and MIPS Imaging of Clusters and Outflows in 9 High-mass Star Forming Regions

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We present *Spitzer* Space Telescope IRAC and MIPS observations toward a sample of nine high-mass star forming regions at a distance of around 2 kpc. Based on IRAC and MIPS 24 μm photometric results and 2MASS *JHKs* data, we carry out a census of young stellar objects (YSOs) in a $5' \times 5'$ field toward each region. Toward seven out of the nine regions, we detect parsec sized clusters with around 20 YSOs surrounded by a more extended and sparse distribution of young stars and protostars. For the other two regions, IRAS 20126+4104 and IRAS 22172+5549, the former has the lowest number of YSOs in the sample and shows no obvious cluster, and the latter appears to be part of a larger, potentially more evolved cluster. The deep IRAC imaging reveals at least twelve outflows in eight out of the nine regions, with nine outflows prominent in the 4.5 μm band most probably attributed to shocked H_2 emission, two outflows dominated by scattered light in the 3.6 and 4.5 μm bands, and one outflow standing out

from its hydrocarbon emission in the 8.0 μm band. In comparison with previous ground-based observations, our IRAC observations reveal new outflow structures in five regions. The dramatically different morphologies of detected outflows can be tentatively interpreted in terms of possible evolution of massive outflows. The driving sources of these outflows are deeply embedded in dense dusty cores revealed by previous millimeter interferometric observations. We detect infrared counterparts of these dusty cores in the IRAC or MIPS 24 μm bands. Reflection nebulae dominated by the emission from UV heated hydrocarbons in the 8.0 μm band can be found in most regions and they may imply the presence of young B stars.

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Magnetorotational instability in protoplanetary discs: The effect of dust grains

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We investigate the linear growth and vertical structure of the magnetorotational instability (MRI) in weakly ionised, stratified protoplanetary discs. The magnetic field is initially vertical and dust grains are assumed to be well mixed with the gas over the entire vertical dimension of the disc. For simplicity, all the grains are assumed to have the same radius ($a = 0.1$, 1 or 3 μm) and constitute a constant fraction (1 %) of the total mass of the gas. Solutions are obtained at representative radial locations ($R = 5$ and 10 AU) from the central protostar for a minimum-mass solar nebula model and different choices of the initial magnetic field strength, configuration of the diffusivity tensor and grain sizes.

We find that when no grain are present, or they are $\gtrsim 1$ μm in radius, the midplane of the disc remains magnetically coupled for field strengths up to a few gauss at both radii. In contrast, when a population of small grains ($a = 0.1$ μm) is mixed with the gas, the section of the disc within two tidal scaleheights from the midplane is magnetically inactive and only magnetic fields weaker than ~ 50 mG can effectively couple to the fluid. At 5 AU, Ohmic diffusion dominates for $z/H < 1$ when the field is relatively weak ($B <$ a few milligauss), irrespective of the properties of the grain population. Conversely, at 10 AU this diffusion term is unimportant in all the scenarios studied here. High above the midplane ($z/H > 5$), ambipolar diffusion is severe and prevents the field from coupling to the gas for all B. Hall diffusion is dominant for a wide range of field strengths at both radii when dust grains are present.

The growth rate, wavenumber and range of magnetic field strengths for which MRI- unstable modes exist are all drastically diminished when dust grains are present, particularly when they are small ($a \sim 0.1\mu$m). In fact, MRI perturbations grow at 5 AU (10 AU) for $B < 160$ mG (130 mG) when 3 μm grains are mixed with the gas. This upper limit on the field strength is reduced to only ~ 16 mG (10 mG) when the grain size is reduced to 0.1 μm. In contrast, when the grains are assumed to have settled, MRI unstable modes are found for $B < 800$ mG at 5 AU and 250 mG at 10 AU (Salmeron & Wardle 2005). Similarly, as the typical size of the dust grains diminishes, the vertical extent of the dead zone increases, as expected. For 0.1 μm grains, the disk is magnetically inactive within two scaleheights of the midplane at both radii, but perturbations grow over the entire section of the disk for grain sizes of 1 μm or larger. When dust grains are mixed with the gas, perturbations that incorporate Hall diffusion grow faster, and are active over a more extended cross section of the disc, than those obtained under the ambipolar diffusion approximation.

Note that the stabilizing effect of small dust grains (e.g. $a = 0.1$ μm) is not strong enough to completely suppress the perturbations. We find, in fact, that even in this scenario the magnetic field is able to couple to the gas and shear over a range of fluid conditions. Despite the low magnetic coupling, MRI modes grow for a range of magnetic field strengths and Hall diffusion largely determines the properties of the perturbations in the inner regions of the disc.

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On the origin of field O-type stars

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Aims: We try to identify the origins of field O-stars in the nearest 2 to 3 kpc around the Sun using the best presently available kinematic data on O-stars and on young open clusters. We investigate the question if the present-day data are consistent with the assumption that O-stars have formed in groups (clusters, associations), or in isolation.
Methods: We apply the epicycle theory for back-tracing the orbits of O-type stars and of candidate parent open clusters.
Results: From the 370 O-stars in the "Galactic O star catalog v 2.0" (GOSV2) we have investigated 93 stars classified as $field$, and found the origin for 73 of them in 48 open clusters younger than 30 Myrs. Only for 32 stars or about 9% of all O-stars from this catalogue, the question of their origin in groups is not solved; some of them may have originated in isolation or may have disintegrated the group in which they formed. Fifty percent of the young open clusters (age $<$ 30 Myr) in the "Catalogue of Open Cluster Data" (COCD) have O-stars as members, or have ejected at least one O-star in the first 10 Myrs of their life, or both. During this period the average mass loss from open clusters by ejecting O-stars is found to be 3 to 5 $M_\odot$ per Myr. We prove that ζ Pup had its origin in the open cluster Trumpler 10 which it left about 2.5 Myrs ago, and that its present-day distance is 300 pc (compared to 440 pc before). The revised distance implies a significant revision of the stellar parameters (a radius of 14 $R_\odot$, a mass of 22.5 $M_\odot$, and a luminosity of log $L/L_\odot$ of 5.74) i.e, ζ Pup is closer, less massive, and less luminous than previously thought. Our findings provide independent estimates of the present-day distances and absolute magnitudes of field O-stars.

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IRAS04325+2402C: A very low mass object with an edge-on disk

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IRAS04325+2402C is a low luminosity object located near a protostar in Taurus. We present new spatially-resolved mm observations, near-infrared spectroscopy, and Spitzer photometry that improve the constraints on the nature of this source. The object is clearly detected in our 1.3 mm interferometry map, allowing us to estimate the mass in a localized disk+envelope around it to be in the range of 0.001 to 0.01 $M_\odot$. Thus IRAS04325C is unlikely to accrete significantly more mass. The near-infrared spectrum cannot be explained with an extincted photosphere alone, but is consistent with a 0.03-0.1 $M_\odot$ central source plus moderate veiling, seen in scattered light, confirming the edge-on nature of the disk. Based on K-band flux and spectral slope we conclude that a central object mass $> 0.1\,M_\odot$ is unlikely. Our comparison of the full spectral energy distribution, including new *Spitzer* photometry, with radiative transfer models confirms the high inclination of the disk ($>$ 80 deg), the very low mass of the central source, and the small amount of circumstellar material. IRAS04325C is one of the lowest mass objects with a resolved edge-on disk known to date, possibly a young brown dwarf, and a likely wide companion to a more massive star. With these combined properties, it represents a unique case to study the formation and early evolution of very low mass objects.

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An assessment of Li abundances in weak-lined and classical T Tauri stars of the Taurus-Auriga association.

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Accurate measurements of lithium abundances in young low-mass stars provide an independent and reliable age diagnostics. Previous studies of nearby star forming regions have identified significant numbers of Li-depleted stars, often at levels inconsistent with the ages indicated by their luminosity. We aim at a new and accurate analysis of Li abundances in a sample of ∼100 pre-main sequence stars in Taurus-Auriga using a homogeneous and updated set of stellar parameters and model atmospheres appropriate for the spectral types of the sample stars. We compute Li abundances using published values of the equivalent widths of the Li λ6708 Å doublet obtained from medium/high resolution spectra. We find that the number of significantly Li-depleted stars in Taurus-Auriga is greatly reduced with respect to earlier results. Only 13 stars have abundances lower than the interstellar value by a factor of 5 or greater. All of them are weak-lined T Tauri stars drawn from X-ray surveys; with the exception of four stars located near the L1551 and L1489 dark clouds, all the Li-depleted stars belong to the class of dispersed low-mass stars, distributed around the main sites of current star formation. If located at the distance of Taurus-Auriga, the stellar ages implied by the derived Li abundances are in the range 3-30 Myr, greater than the bulk of the Li-rich population with implication on the star formation history of the region. In order to derive firm conclusions about the fraction of Li-depleted stars of Taurus-Auriga, Li measurements of the remaining members of the association should be obtained, in particular of the group of stars that fall in the Li-burning region of the HR diagram.

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The Challenge of Sub-Keplerian Rotation for Disk Winds

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Strong magnetization makes the disks surrounding young stellar objects rotate at rates that are too sub-Keplerian to enable the thermal launching of disk winds from their surfaces unless the rate of gas diffusion across field lines is dynamically fast. This underappreciated implication of disk magnetization poses a considerable challenge for disk-wind theory.

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Very Low-Mass Objects in the Coronet Cluster: The Realm of the Transition Disks

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We present optical and IR spectra of a set of low-mass stars and brown dwarfs in the Coronet cluster (aged ∼1 Myr), obtained with the multifiber spectrograph FLAMES on the VLT and with the IRS instrument on Spitzer. Most of the objects had been selected via their X-ray emission in a deep Chandra survey. The optical spectra reveal spectral types between M1 and M7.5, confirm the youth of the objects (via Li 6708 Å absorption), and show the presence of accretion (via Hα) and shocks (via forbidden line emission). The IRS spectra, together with IR photometry from the

IRAC/MIPS instruments on Spitzer and 2MASS, confirm the presence of IR excesses characteristic of disks around ~70% of the objects. Half of the disks do not exhibit any silicate emission, or present flat features characteristic of large grains (>6 μm). The rest of the disks show silicate emission with indications of amorphous and crystalline silicate grains a few microns in size. About 50% of the objects with disks do not show near-IR excess emission, corresponding to the presence of "transitional" disks, according to their classical definition. This is a very high fraction for such a young cluster. The large number of "transitional" disks suggests lifetimes comparable to the lifetimes of typical optically thick disks. Therefore, these disks may not be in a short-lived phase, intermediate between Class II and Class III objects. The median spectral energy distribution of the disks in the Coronet cluster is also closer to a flat disk than observed for the disks around solar-type stars in regions with similar age. The differences in the disk morphology and evolution in the Coronet cluster could be related to fact that these objects have very late spectral types compared to the solar-type stars in other cluster studies. Finally, the optical spectroscopy reveals that one of the X-ray sources is produced by a Herbig Haro object in the cloud.

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http://www.mpia.de/homes/sicilia/aurora.html

The initial conditions of star formation VIII: an observational study of the Ophiuchus cloud L1688 and implications for the prestellar core mass function

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We re-analyse all of the archive observations of the Ophiuchus dark cloud L1688 that were carried out with the submillimetre common-user bolometer array (SCUBA) at the James Clerk Maxwell Telescope (JCMT). For the first time we put together all of the data that were taken of this cloud at different times to make a deeper map at 850μm than has ever previously been published. Using this new, deeper map we extract the pre-stellar cores from the data. We use updated values for the distance to the cloud complex, and also for the internal temperatures of the pre-stellar cores to generate an updated core mass function (CMF). This updated CMF is consistent with previous results in so far as they went, but our deeper map gives an improved completeness limit of 0.1$M_\odot$ (0.16 Jy), which enables us to show that a turnover exists in the low-mass regime of the CMF. The L1688 CMF shows the same form as the stellar IMF and can be mapped onto the stellar IMF, showing that the IMF is determined at the prestellar core stage. We compare L1688 with the Orion star-forming region and find that the turnover in the L1688 CMF occurs at a mass roughly a factor of two lower than the CMF turnover in Orion. This suggests that the position of the CMF turnover may be a function of environment.

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Surprising dissimilarities in a newly formed pair of 'identical twin' stars

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The mass and chemical composition of a star are the primary determinants of its basic physical properties—radius, temperature and luminosity—and how those properties evolve with time. Accordingly, two stars born at the same time, from the same natal material and with the same mass, are 'identical twins,' and as such might be expected to possess identical physical attributes. We have discovered in the Orion nebula a pair of stellar twins in a newborn binary star system. Each star in the binary has a mass of 0.41 ± 0.01 solar masses, identical to within 2 per cent. Here

we report that these twin stars have surface temperatures differing by 300 K (10 per cent) and luminosities differing by 50 per cent, both at high confidence level. Preliminary results indicate that the stars' radii also differ, by 5–10 per cent. These surprising dissimilarities suggest that one of the twins may have been delayed by several hundred thousand years in its formation relative to its sibling. Such a delay could only have been detected in a very young, definitively equal-mass binary system. Our findings reveal cosmic limits on the age synchronization of young binary stars, often used as tests for the age calibrations of star-formation models.

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http://people.vanderbilt.edu/∼keivan.stassun/pubs.htm

Spitzer Observations of Bok Globule B335: Isolated Star Formation Efficiency and Cloud Structure

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We present infrared and millimeter observations of Barnard 335, the prototypical isolated Bok globule with an embedded protostar. Using *Spitzer* data we measure the source luminosity accurately; we also constrain the density profile of the innermost globule material near the protostar using the observation of an 8.0 μm shadow. *HHT* observations of ^{12}CO $2-1$ confirm the detection of a flattened molecular core with diameter $\sim$10000 AU and the same orientation as the circumstellar disk ($\sim$100 to 200 AU in diameter). This structure is probably the same as that generating the 8.0 μm shadow and is expected from theoretical simulations of collapsing embedded protostars. We estimate the mass of the protostar to be only $\sim$5% of the mass of the parent globule.

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The Photon Dominated Region in the IC 348 molecular cloud

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In this paper we discuss the physical conditions of clumpy nature in the IC 348 molecular cloud. We show that the millimeter and sub-millimeter line emission from the IC 348 molecular cloud can be modelled as originating from a photon dominated region (PDR).

We combine new observations of fully sampled maps in [C I] at 492 GHz and 12CO 4–3, taken with the KOSMA 3 m telescope at about 1' resolution, with FCRAO data of 12CO 1–0, 13CO 1–0 and far-infrared continuum data observed by HIRES/IRAS. To derive the physical parameters of the region we analyze the line ratios of [C I] 3P1–3P0 / 12CO 4–3, [C I] 3P1–3P0 /1 3CO 1–0, and 12CO 4–3 / 12CO 1–0. A first rough estimate of abundance is obtained from an LTE analysis. To understand the [C I] and CO emission from the PDRs in IC 348, we use a clumpy PDR model. With an ensemble of identical clumps, we constrain the total mass from the observed absolute intensities. Then we

apply a more realistic clump distribution model with a power law index of 1.8 for clump-mass spectrum and a power law index of 2.3 for mass-size relation.

We provide detailed fits to observations at seven representative positions in the cloud, revealing clump densities between 4 10^4 cm^{-3} and 4 10^5 cm^{-3} and C/CO column density ratios between 0.02 and 0.26. The derived FUV flux from the model fit is consistent with the field calculated from FIR continuum data, varying between 2 and 100 Draine units across the cloud. We find that both an ensemble of identical clumps and an ensemble with a power law clump mass distribution produce line intensities which are in good agreement (within a factor 2) with the observed intensities. The models confirm the anti-correlation between the C/CO abundance ratio and the hydrogen column density found in many regions.

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A Two-Fluid Method for Ambipolar Diffusion

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We present a semi-implicit method for isothermal two-fluid ion-neutral ambipolar drift that is second-order accurate in space and time. The method has been implemented in the RIEMANN code for astrophysical fluid dynamics. We present four test problems that show the method works and correctly tracks the propagation of MHD waves and the structure of two-fluid C-shocks. The accurate propagation of MHD waves in the two-fluid approximation is shown to be a stringent test of the algorithm. We demonstrate that highly accurate methods are required in order to properly capture the MHD wave behaviour in the presence of ion-neutral friction.

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A multiwavelength investigation of G24.78+0.08 A2 using observations from VLA and VLT-VISIR

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Context. G24.78+0.08 is a massive star-forming region where three large massive disk-like rotating structures (toroids), namely A1, A2 and C, have been found around massive (proto)stars. In particular, while G24 A1 has been extensively investigated through multiwavelength surveys, G24 A2 has been hitherto less studied.
Aims. We carry out a detailed investigation of G24 A2 and speculate the scenario of the environment in the vicinity of the central exciting object(s).
Methods. We have carried out mid-infrared imaging observations of the G24.78+0.08 region at 11.9 and 18.7 μm using the VISIR located on the VLT. In addition, the radio continuum VLA observations at 1.3 cm as well as the NH_3 (2,2) line emission have been investigated.
Results. Compact mid-infrared emission is observed only from one source in the G24.78+0.08 region and this is likely to be associated with G24 A2. The radio continuum measurements show a faint compact source which is resolved out at higher angular resolutions (60 mas); the diameter D of the radio emitting region is estimated to be 1000 AU $<$ D $<$ 2000 AU. The spectral index ($\sim$1) points towards the possibility of this emission being from an ionised jet or an HII region with a density gradient. The NH_3 (2,2) emission from the main component is optically thick and appears self-absorbed at blue-shifted velocities. The velocity distributions of the NH_3 lines can be explained by a motion which is a combination of rotation and expansion. Based on these observations, we speculate that the expansion is due to the outflow (seen in CO) with A2 being the likely origin of this outflow. The comparison of various properties of G24 A1

and G24 A2 like rotation, mass of cores, infrared emission, excitation temperature, suggests that G24 A2 and G24 A1 possibly harbour similar young stellar objects, but the toroid associated with G24 A2 is more inclined than that of G24 A1.

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http://www.arcetri.astro.it/~starform/preprints/vig_01.pdf

Infrared study of the southern Galactic star forming regions associated with IRAS 10049-5657 and IRAS 10031-5632

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We investigate the physical conditions of the interstellar medium and stellar components in the regions of the southern Galactic star forming complexes associated with IRAS 10049-5657 and IRAS 10031-5632. These regions have been mapped simultaneously in two far infrared bands ($\lambda_{eff} \sim 150$ & 210 μm), with $\sim 1'$ angular resolution using the TIFR 1-m balloon borne telescope. Spatial distribution of the temperature of cool dust and optical depth at 200 μm have been obtained taking advantage of the similar beams in the two bands. The HIRES processed IRAS maps at 12, 25, 60 and 100 μm have been used for comparison. Using the 2MASS near infrared sources, we find the stellar populations of the embedded young clusters. A rich cluster of OB stars is seen in the IRAS 10049-5657 region. The fits to the stellar density radial profile of the cluster associated with IRAS 10049-5657 has been explored with inverse radius profile as well as the King's profile; the cluster radius is obtained to be ~ 2 pc. The source in the cluster closest to the IRAS peak is IRA-7 which lies above the zero age main sequence curve of spectral type O5 in the colour-magnitude diagram. Unlike IRAS 10049-5657, a small cluster comprising of a few deeply embedded sources is seen at the location of IRAS 10031-5632. Self consistent radiative transfer modelling aimed at extracting important physical and geometrical details of the two IRAS sources show that the best fit models are in good agreement with the observed spectral energy distributions. The geometric details of the associated cloud and optical depths (τ_{100}) have been estimated. A uniform density distribution of dust and gas is implied for both the sources. In addition, the infrared ionic fine-structure line emission from gas has been modelled for both these regions and compared with data from IRAS-Low Resolution Spectrometer. For IRAS 10049-5657, the observed and modelled luminosities for most lines agree to within a factor of four while for IRAS 10031-5632, we find a discrepancy of a factor of 100 and it is likely that some basic assumptions of the model are not valid in this case.

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On the Formation of Compact Stellar Disks Around Sgr A*

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The recent identification of one or two sub-parsec disks of young, massive stars orbiting the $\sim 4\times10^6$ $M_\odot$ black hole Sgr A* has prompted an "in-situ" scenario for star formation in disks of gas formed from a cloud captured from the Galactic center environment. To date there has been no explanation given for the low angular momentum of the disks relative to clouds passing close to the center. Here we show that the partial accretion of extended Galactic center clouds, such as the 50 km$\cdot$s^{-1} giant molecular cloud, that temporarily engulf Sgr A* during their passage through the central region of the Galaxy provide a natural explanation for the angular momentum and surface density of the the observed stellar disks. The captured cloud material is gravitationally unstable and forms stars as it circularizes, potentially explaining the large eccentricity and range of inclinations of the observed stellar orbits. The application of this idea to the formation of the circumnuclear ring is also discussed.

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Spitzer SAGE Survey of the Large Magellanic Cloud: III. Star Formation and ~ 1000 New Candidate Young Stellar Objects

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We present ~ 1000 new candidate Young Stellar Objects (YSOs) in the Large Magellanic Cloud (LMC) selected from *Spitzer* Space Telescope data, as part of the Surveying the Agents of a Galaxy's Evolution (SAGE) Legacy program. The YSOs, detected by their excess infrared emission, represent early stages of evolution, still surrounded by disks and/or infalling envelopes. Previously, fewer than 20 such YSOs were known. The candidate YSOs were selected from the SAGE point source catalog from regions of color-magnitude space least confused with other IR-bright populations. The YSOs are biased towards intermediate- to high-mass and young evolutionary stages, because these overlap less with galaxies and evolved stars in color-magnitude space. The YSOs are highly correlated spatially with atomic and molecular gas, and are preferentially located in the shells and bubbles created by massive stars inside. They are more clustered than generic point sources, as expected if star formation occurs in filamentary clouds or shells. We applied a more stringent color-magnitude selection to produce a subset of "high-probability" YSO candidates. We fit the SEDs of this subset and derived physical properties for those that were well-fit. The total mass of these well-fit YSOs is $\sim 2900 M_{\odot}$ and the total luminosity is $\sim 2.1 \times 10^6 L_{\odot}$. By extrapolating the mass function with a standard initial mass function and integrating, we calculate a current star formation rate of $\sim 0.06 M_{\odot}$/yr, which is at the low-end of estimates based on total ultraviolet and infrared flux from the galaxy ($\sim 0.05 - 0.25 M_{\odot}$/yr); consistent with the expectation that our current YSO list is incomplete. Followup spectroscopy and further data mining will better separate the different IR-bright populations and likely increase the estimated number of YSOs. The full YSO list is available as electronic tables, and the SEDs are available as an electronic figure for further use by the scientific community.

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Problems of Star Formation Theory and Prospects of Submillimeter Observations

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We consider current state of star formation theory and requirements to observations in millimeter and submillimeter ranges which are necessary for resolution of the most actual problems of the physics of star formation. Two key features of star-forming regions which define observational requirements to their studies, are relatively low energy of processes that take place there and smallness of corresponding spatial scales. This is especially true for the objects in the latest stages of "pre-stellar" evolution, that is, hot cores, hyper- and ultracompact HII regions, and protoplanetary disks. Angular resolution, sensitivity, and spectral coverage in existing projects of ground-based and space telescopes of submillimeter and millimeter range are not completely adequate to necessary requirements. To obtain detailed information on star-forming regions as well as on individual protostars it is necessary to employ a space-based interferometer.

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Massive Star Formation in the Molecular Ring Orbiting the Black Hole at the Galactic Center

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A ring of dense molecular gas extending 2-7 pc orbits the supermassive black hole Sgr A* at the center of our Galaxy. Using the Green Bank Telescope, we detected water maser lines and both narrow (0.35 km s^{-1}) and broad (30 - 50 km s^{-1}) methanol emission from the molecular ring. Two of the strongest methanol lines at 44 GHz are confirmed as masers by interferometric observations. These class I methanol masers are collisionally excited and are signatures of early phases of massive star formation in the disk of the Galaxy, suggesting that star formation in the molecular ring is in its early phase. Close inspection of the kinematics of the associated molecular clumps in the HCN (J=1-0) line reveals broad red-shifted wings indicative of disturbance by protostellar outflows from young (few $\times 10^4$ yrs), massive stars embedded in the clumps. The thermal methanol profile has a similar shape, with a narrow maser line superimposed on a broad, red-shifted wing. Additional evidence for the presence of young massive protostars is provided by shocked molecular hydrogen and a number of striking ionized and molecular linear filaments in the vicinity of methanol sources suggestive of 0.5-pc scale protostellar jets. Given that the circumnuclear molecular ring is kinematically unsettled and thus is likely be the result of a recent capture, the presence of both methanol emission and broad, red-shifted HCN emission suggests that star formation in the circumnuclear ring is in its infancy.

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Unveiling a Compact Cluster of Massive and Young Stars in IRAS 17233-3606

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We have analyzed sensitive high spatial resolution archival radio continuum data at 1.3, 2.0, 3.6 and 6.0 cm as well as the H_2O maser molecular line data obtained using the Very Large Array (VLA) in its hybrid AB configuration toward the high-mass star-forming region IRAS 17233-3606 (G351.78-0.54). We find nine compact radio sources associated with this region, six of them are new radio detections. We discuss the characteristics of these sources based mostly on their spectral indices and find that most of them appear to be optically thin or thick ultra- and hyper-compact HII regions ionized by B ZAMS stars. Furthermore, in a few cases the radio emission may arise from optically thick dusty disks and/or cores, however more observations at different wavelengths are necessity to firmly confirm their true nature. In addition, we compared our centimeter maps with the mid-infrared images from the Spitzer Space Observatory GLIMPSE survey revealing a cluster of young protostars in the region together with multiple collimated outflows some of whom might be related with the compact centimeter objects. Finally, we find that one of these centimeter objects, VLA2d, is well centered in an apparent strong and compact north-south bipolar outflow traced by OH masers and we therefore suggest that this object maybe is energizing the latter.

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Long-wavelength excesses of FU Orionis objects: flared outer disks or infalling envelopes?

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The mid- to far-infrared emission of the outbursting FU Orionis objects has been attributed either to a flared outer disk or to an infalling envelope. We revisit this issue using detailed radiative transfer calculations to model the recent, high signal-to-noise data from the IRS instrument on the Spitzer Space Telescope. In the case of FU Ori, we find that a physically-plausible flared disk irradiated by the central accretion disk matches the observations. Building on our previous work, our accretion disk model with outer disk irradiation by the inner disk reproduces the spectral energy distribution between 4000 angstroms to 40 microns. Our model is consistent with near-infrared interferometry but there are some inconsistencies with mid-infared interferometric results. Including the outer disk allows us to refine our estimate of the outer radius of the outbursting, high mass accretion rate disk in FU Ori as 0.5 AU, which is a crucial parameter in assessing theories of the FU Orionis phenomenon. We are able to place an upper limit on the mass infall rate of any remnant envelope infall rate to 7e-7 Msun/yr assuming a centrifugal radius of 200 AU. The FUor BBW 76 is also well modelled by a 0.6 AU inner disk and a flared outer disk. However, V1515 Cyg requires an envelope with an outflow cavity to adequately reproduce the IRS spectrum. In contrast with the suggestion by Green et al., we do not require a flattened envelope to match the observations; the inferred cavity shape is qualitatively consistent with typical protostellar envelopes. This variety of dusty structures suggests that the FU Orionis phase can be present at either early or late stages of protostellar evolution.

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Abstracts of recently accepted major reviews

Evolution of Debris Disks

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Circumstellar dust exists around several hundred main sequence stars. For the youngest stars that dust could be a remnant of the protoplanetary disk. Mostly it is inferred to be continuously replenished through collisions between planetesimals in belts analogous to the Solar System's asteroid and Kuiper belts, or in collisions between growing protoplanets. The evolution of a star's debris disk is indicative of the evolution of its planetesimal belts and may be influenced by planet formation processes, which can continue throughout the first gigayear as the planetary system settles to a stable configuration and planets form at large radii. Evidence for that evolution comes from infrared photometry of large numbers of debris disks, providing snapshots of the dust present at different evolutionary phases, as well as from images of debris disk structure. This review describes the theoretical framework within which debris disk evolution takes place and shows how that framework has been constrained by observations.

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Unravelling the Mysteries of Galactic Titans: Star Formation in Massive Clusters

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Young stellar clusters play a fundamental role in the universe as the preferred sites of star and planet formation. The winds and outflows produced by the newly born stars are an important source of turbulence promoting the mixing and metal enrichment of the interstellar medium (ISM). Massive stars, only found in the most massive clusters, produce the high-energy radiation and cosmic rays that regulate the chemistry of the ISM. Their short lives give raise to expanding HII regions and to supernova explosions that will act globally on the dynamics of the galaxy, and locally on the molecular clouds, eventually triggering new generations of clusters. The goal of this thesis is to use unprecedented resolution and depth near-infrared photometric data to characterise the embedded populations of three Milky Way young clusters (Westerlund 2, Trumpler 14, and RCW 38) with massive star content, and explore whether star formation in massive clusters is an extension of the well-characterised low-mass clustered star formation.

As the most immediate result we validate photometry as a powerful tool for the study of embedded clusters. Lacking the detailed individual scrutiny of spectroscopic observations, photometry is the only way to detect and study most of the cluster's population, as the most abundant, low-mass objects are typically too faint for spectroscopy. Moreover, it allows for a global characterisation of the cluster properties within the constraints of telescope time. Near-infrared data are particularly suited for these studies as they successfully penetrate into the molecular cloud and efficiently expose the cluster members.

Having developed the analytical tools to extract the most information from the data, we reveal three exceedingly interesting clusters. To a first approximation, they all present centrally concentrated structures, contrasting with a significant fraction of hierarchical low-mass clusters. However, unlike Westerlund 2 and RCW 38, Trumpler 14 exhibits an extended halo mostly composed of pre-main sequence objects, accompanied by a low central stellar density when compared to other clusters that massive.

These structural differences may be fundamental in defining the modes of cluster formation and the influence of the environment. Also revealing is the fact that the centre of the stellar density profile, and presumably the centre of the cluster's potential well, is not coincident with the position of the most massive star for all three clusters.

We measure a small fraction of disk-bearing stars when compared to that of low-mass clusters of the same age, suggesting that either disks have more difficulty forming in crowded environments, that they cannot survive as long under the influence of the massive stars, or even that they evolve faster into planets in UV-dominated conditions. The finding here of two likely photoevaporating proplyds in the cores of Trumpler 14 and RCW 38 argues for a high disk depletion rate at least within some radius of the massive stars. However, and surprising as it may be, we find that the mass function of these massive clusters is still compatible with Salpeter down to one solar mass suggesting that, even if the circumstellar material is destroyed, their low-mass host stars are allowed to form and survive in the same proportion as in the low-mass clusters, and are hence not significantly affected by the presence of massive stars and

excessive crowding conditions. This could ultimately imply that either the radius of influence of the massive stars is very small, or the low-mass stars are already fully assembled by the time the massive stars ignite.

The distance and direction of these clusters place them well outside the galactic centre, dismissing it as the only site for the formation of massive clusters in the Galaxy. Instead, massive clusters seem to trace the structure of the spiral arms, following the distribution of dense gas in the Galaxy.

Finally, using synthetic clusters built with Monte Carlo simulations, we find that there is currently no observational evidence for mass segregation in massive clusters. The crowding in the dense cores of these clusters, combined with the limited resolution of current telescopes, results in a radially dependent incompleteness that effectively mimics the effects of mass segregation. Moreover, we show that we cannot properly account for this incompleteness, which severely hinders the assessment of mass segregation.

2-Year Postdoctoral Fellowship in Star Formation

Applications are invited for a 2-year postdoctoral fellowship in the Dublin Institute for Advanced Studies to work in the Star Formation Group. This is a Science Foundation Ireland funded project supporting the international Gould Belt Survey http://www.cfa.harvard.edu/gouldbelt/related.html to be undertaken by a number of ground-based and space-based facilities including Spitzer, UKIRT, Herschel, APEX and JCMT. Ideally the appointed person will have experience in infrared or mm observational astronomy in the context of star formation.

Further details can be obtained from Prof Tom Ray tr *at* cp.dias.ie to whom inquiries should be directed. A CV, and the names of three referees, should be sent to Eileen Flood eflood *at* cp.dias.ie by 31st August 2008.

DIAS is an equal opportunity employer

2 Advanced Postdoctoral positions at CAUP Porto, Portugal: Star Formation

The Centro de Astrofísica da Universidade do Porto (CAUP) opens a call for 2 Advanced Postdoctoral Researchers. The positions are for 5 years starting before the end of 2008. The net yearly income is above 42 000 euros (before taxes) corresponding to the salary of an Assistant Professor.

CAUP is the largest Astronomy research institute in Portugal, evaluated as Excellent by an international panel under the auspices of Fundação para a Ciência e a Tecnologia (FCT). The Strategic Development Plan of CAUP is built around: scientific excellence; public outreach; national networking; internationalization; financial stability. The objective of CAUP is to be an institute with internationally recognized front-line research and to be actively involved with the leading institutes in Europe on the areas identified as the focus of its research activity.

The contracts are aimed at researchers with expertise in any of the areas currently represented at the institute. Star Formation and Early Evolution is one of the science topics addressed by the teams at CAUP. Candidates with a profile adequate to contribute to these fields will be considered in this call.

The applicants should have a relevant scientific curriculum and publication record and have significant experience in their field of research. They will be expected to supervise research students and to propose and conduct new research projects and funding applications (national and international), as well as lead the participation in relevant international initiatives in their field of research. Three years experience as a postdoc is preferred, although exceptions may be considered. The positions will be filled, following the proposal by the Selection Committee and final decision by FCT.

The application, to be submitted by email (PDF files are preferred), should include a Curriculum Vitae (up to 4 pages); a complete list of publications; a description of research experience and plans (up to 3 pages); names and contact details (position, email, address) of three referees. The candidates may be required to present a seminar (up to 30 minutes) and participate in an interview. For the full description of the positions and applications please see the CAUP webpage http://www.astro.up.pt/

Applications deadline is 22th of September, 2008.

For inquires and submission of applications please contact: Prof. Doutor Mário J. P. F. G. Monteiro.

SECOND ANNOUNCEMENT

New Light on Young Stars: Spitzer's View of Circumstellar Disks

October 26-30 2008, Hilton Hotel, Pasadena CA

http://www.ipac.caltech.edu/spitzer2008

FRIDAY AUGUST 8 is the abstract deadline for contributed talks and for early registration at the reduced rate of $250. Talks and posters are solicited in the following topic areas:

* Surveys of star-formation regions
Effects of environment and central object on disk properties
Structure of protostellar/protoplanetary disks and envelopes
Spectroscopic diagnostics of circumstellar gas and dust
Transition disks, disk evolution, and planet formation
Frequency, structure, and theory of debris disks

Cosmic Cataclysms and Life

10 - 14 November 2008, ESRIN, Frascati, Italy

Website: http://www.congrex.nl/08c16/

A number of cataclysms have occurred in the history of the universe and the Solar System. The Symposium will review those that had a critical influence on the evolution of habitable worlds and on the emergence and survival of life on Earth, and possibly elsewhere.

Confirmed Invited Speakers

L. Ziurys, J. Truran (Chicago), J. Blum (Braunschweig), J. Greeves (St Andrews), A. Morbidelli (Nice), D. Kring (Arizona) , G. Horneck (Koln), D. Prieur (Brest), P. Ehrenfreund (Washington), K.-H. Glassmeier (Braunschweig), I. Ribas (Madrid), B. Thomas (Washburn), F. Selsis (Bordeaux), T. Owen (Hawaii), V. Trimble (Irvine), E. Pilat-Lohinger (Vienna)

Programme

Monday 10 November 2008
Introduction: Cosmic Cataclysms: the biological overview
Session 1: Big Bang and Nucleosynthesis

Tuesday 11 November 2008
Session 2: Star Formation and Synthesis of Molecules
Session 3: Planetary formation and the role of collisions

Wednesday 12 November 2008
Session 4: Late Heavy Bombardment, the Moon-Earth System and the Emergence of Life on Earth
Session 5: The Role of Impacts on Life

Thursday 13 November 2008
Session 6: Emergence and habitats of life for the Universe
Session 7: Hazards from the Sun, Stars and the universe and resilience of Life

Friday 14 November 2008
Session 8: Cosmic habitability, prevalence of Earth-like planets and the fate of the Earth

Planet Formation

This is the first announcement of a solar-extrasolar planet formation meeting to take place at NASA Ames on the 5-6 (and possibly 7 depending on the level of interest) of February 2009.

Reconciling observations of extrasolar planets with those of the solar system will engage the efforts of planetary formation observers and theorists for the forseeable future. The aim of this meeting is to promote cross-fertilization between the extrasolar and the solar planetary communities. The topics will include both theoretical and observational characterization of protostars and planets. The emphasis of the meeting will be to compare and contrast planetary systems. Ideally, constraints derived from diverse planetary systems will be complementary; yet, the extent to which such systems can be viewed under a common prism remains to be clarified. Talks seeking to shed light on this issue will be particularly encouraged.

Here is a preliminary list of invited speakers:

James Green (NASA HQ), James Graham (Berkeley), Re'em Sari (Caltech), Jeremy Goodman (Princeton), Roman Rafikov (Princeton), Jack Lissauer (NASA Ames), Uma Gorti(NASA/SETI), Hilke Schlichting (Caltech), David Charbonneau (CFA), Scott Sandford (NASA Ames), Eugene Chiang (Berkeley), Michael Meyer (U. of Arizona), Yoram Lithwick (CITA), Joan Najita (NOAO), Mark Marley (NASA Ames), Ignacio Mosqueira (NASA/SETI)

If you would like to attend this meeting please contact me at mosqueir *at* cosmic.arc.nasa.gov

We look forward to an exciting and productive meeting.

Sincerely,
Ignacio Mosqueira