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Abstracts of recently accepted papers

On the interplay between flaring and shadowing in disks around Herbig Ae/Be stars.

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Based on the SED, Herbig stars have been categorized into two observational groups, reflecting their overall disk structure: group I members have disks with a higher degree of flaring than their group II counterparts. We investigate the 5-35 um Spitzer IRS spectra of a sample of 13 group I sources and 20 group II sources. We focus on the continuum emission to study the underlying disk geometry. We have determined the [30/13.5] and [13.5/7] continuum flux ratios. The 7-um flux excess with respect to the stellar photosphere is measured, as a marker for the strength of the near-IR emission produced by the inner disk. We have compared our data to self-consistent passive-disk model spectra, for which the same quantities were derived.

We confirm the literature result that the difference in continuum emission between group I and II sources can largely be explained by a different amount of small dust grains. However, we report a strong correlation between the [30/13.5] and [13.5/7] flux ratios for Meeus group II sources. Moreover, the [30/13.5] flux ratio decreases with increasing 7-um excess for all targets in the sample. To explain these correlations with the models, we need to introduce an artificial scaling factor for the inner disk height. In roughly 50stars in our sample, the inner disk must be inflated by a factor 2 to 3 beyond what hydrostatic calculations predict. The total disk mass in small dust grains determines the degree of flaring. We conclude, however, that for any given disk mass in small dust grains, the shadowing of the outer (tens of AU) disk is determined by the scale height of the inner disk (1 AU). The inner disk partially obscures the outer disk, reducing the disk surface temperature. Here, for the first time, we prove these effects observationally.

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General Analysis of Type I Planetary Migration with Stochastic Perturbations

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This paper presents a generalized treatment of Type I planetary migration in the presence of stochastic perturbations. In many planet-forming disks, the Type I migration mechanism, driven by asymmetric torques, acts on a short time scale and compromises planet formation. If the disk also supports MHD instabilities, however, the corresponding turbulent fluctuations produce additional stochastic torques that modify the steady inward migration scenario. This work studies the migration of planetary cores in the presence of stochastic fluctuations using complementary methods, including a Fokker-Planck approach and iterative maps. Stochastic torques have two main effects: [1] Through outward diffusion, a small fraction of the planetary cores can survive in the face of Type I inward migration. [2] For a given starting condition, the result of any particular realization of migration is uncertain, so that results must be described in terms of the distributions of outcomes. In addition to exploring different regimes of parameter space, this paper considers the effects of the outer disk boundary condition, varying initial conditions, and time-dependence of the torque parameters. For disks with finite radii, the fraction of surviving planets decreases exponentially with time. We find the survival fractions and decay rates for a range of disk models, and find the expected distribution of locations for surviving planets. For expected disk properties, the survival fraction lies in the range $0.01 < p_S < 0.1$.

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Linear Polarization in Forbidden Lines of the T Tauri Star RY Tauri

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We performed high-dispersion spectropolarimetry for the T Tauri star and measured linear polarization in seven forbidden lines of [OI] $\lambda\lambda$ 5577, 6300, 6364, [NII] λ 6583, [SII] $\lambda\lambda$ 6716, 6731, and [FeII] λ 7155. This is the first high-dispersion spectropolarimetry for forbidden lines in T Tauri stars. We successfully detected intrinsic polarization in the [OI] λ 6300 line. The intrinsic [OI] λ 6300 polarization corrected for the foreground polarization was derived as $p_{[OI]} = 1.17 \pm 0.54\%$ and $\theta_{[OI]} = 107° \pm 13°$, whereas the polarization of the nearby continuum was $p_{cont} = 2.4$-3.1% and $\theta_{cont} = 2°$-$11°$. The position angle of [OI] λ6300 polarization is compared with the circumstellar structures found by previous studies. It is nearly perpendicular to the disk long-axis and parallel to the optical Hα jet. Both the perpendicularity and parallelism potentially suggest relatively axisymmetric distribution of the [OI] λ 6300 emitting region and surrounding scattering medium. We constructed a simplified scattering model composed of a point source on a jet axis as an [OI] λ 6300 emitter and a flat disk with an inner hole as a scatterer. Applying the observed polarization to the model suggests that the [OI] λ 6300 emission emerges close to the central star with a possible separation of less than a few $\times$ 0.1 AU.

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V1647 Orionis: Optical Photometric and Spectroscopic Monitoring through the 2003–2006 Outburst

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We present results from an optical imaging and spectroscopic monitoring campaign on the young, low-mass eruptive variable star V1647 Orionis. The star and associated nebulosity (McNeil's Nebula) were observed over the period February 2004 to February 2006 with observations commencing a few months after the original outburst event occurred. Using the Gemini North telescope, we obtained multi-band optical imaging photometry and medium-resolution long-slit spectroscopy of V1647 Ori on an approximately monthly interval. During this period, V1647 Ori remained at, or close to, peak brightness and then faded by 5 magnitudes to close to its pre-outburst brightness. This implies an

outburst timescale of around 27 months. Spectral features seen in both emission and absorption varied considerably during the monitoring period. For example, the Hα line changed significantly in both intensity and profile. We present and discuss the observed photometric and spectroscopic changes and consider how this eruptive event relates to the early formative stages of low-mass stars.

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Studies of Molecular Clouds Associated with H II Regions: S175

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We are studying the impact of H II regions on star formation in their associated molecular clouds. In this paper, we present James Clerk Maxwell Telescope R x A molecular line observations of S175 and environs. This is the first within a sample of 10 H II regions and their surrounding molecular clouds selected for our study. We first make $7' \times 7'$ maps in ^{12}CO(2-1), which are used to investigate the structure of the cloud and to identify individual clumps. Single point observations were made in ^{13}CO(2-1) and CS(5-4) at the peak of the ^{12}CO(2-1) emission within each clump in order to measure the physical properties of the gas. Densities, temperatures, clump masses, peak velocities, and line widths were measured and calculated using these observations. We have identified two condensations (S175A and S175B) in the molecular cloud associated with this H II region. S175A is adjacent to the ionization front and is expected to be affected by the H II region, while S175B is too distant to be disturbed. We compare the structure and gas properties of these two regions to investigate how the molecular gas has been affected by the H II region. S175A has been heated by the H II region and partially compressed by the ionized gas front, but contrary to our expectation it is a quiescent region while S175B is very turbulent and dynamically active. Our investigation for the source of turbulence in S175B resulted in the detection of an outflow within this region.

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The dependence of star formation on initial conditions and molecular cloud structure

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We investigate the dependence of stellar properties on the initial kinematic structure of the gas in star-forming molecular clouds. We compare the results from two large-scale hydrodynamical simulations of star cluster formation that resolve the fragmentation process down to the opacity limit, the first of which was reported by Bate, Bonnell & Bromm. The initial conditions of the two calculations are identical, but in the new simulation the power spectrum of the velocity field imposed on the cloud initially and allowed to decay is biased in favour of large-scale motions. Whereas the calculation of Bate et al. began with a power spectrum $P(k) \propto k^{-4}$ to match the Larson scaling relations for the turbulent motions observed in molecular clouds, the new calculation begins with a power spectrum $P(k) \propto k^{-6}$.

Despite this change to the initial motions in the cloud and the resulting density structure of the molecular cloud, the stellar properties resulting from the two calculations are indistinguishable. This demonstrates that the results of such hydrodynamical calculations of star cluster formation are relatively insensitive to the initial conditions. It is also consistent with the fact that the statistical properties of stars and brown dwarfs (e.g. the stellar initial mass function) are observed to be relatively invariant within our Galaxy and do not appear to depend on environment.

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Animations and paper available at http://www.astro.ex.ac.uk/people/mbate/Cluster/cluster4.html
Also available at http://arxiv.org/abs/0905.3562

The History of the Solar System's Debris Disc: Observable Properties of the Kuiper Belt

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The Nice model of Gomes et al. (2005) suggests that the migration of the giant planets caused a planetesimal clearing event which led to the Late Heavy Bombardment (LHB) at 880 Myr. Here we investigate the IR emission from the Kuiper belt during the history of the Solar System as described by the Nice model. We describe a method for easily converting the results of n-body planetesimal simulations into observational properties (assuming black-body grains and a single size distribution) and further modify this method to improve its realism (using realistic grain properties and a three-phase size distribution). We compare our results with observed debris discs and evaluate the plausibility of detecting an LHB-like process in extrasolar systems. Recent surveys have shown that 4% of stars exhibit 24 μm excess and 16% exhibit 70 μm excess. We show that the Solar System would have been amongst the brightest of these systems before the LHB at both 24 and 70 μm. We find a significant increase in 24 μm emission during the LHB, which rapidly drops off and becomes undetectable within 30 Myr, whereas the 70 μm emission remains detectable until 360 Myr after the LHB. Comparison with the statistics of debris disc evolution shows that such depletion events must be rare occurring around less than 12% of Sun-like stars and with this level of incidence we would expect approximately 1 of the 413 Sun-like, field stars so far detected to have a 24 μm excess to be currently going through an LHB. We also find that collisional processes are important in the Solar System before the LHB and that parameters for weak Kuiper belt objects are inconsistent with the Nice model interpretation of the LHB.

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Tracing the inner edge of the disk around HD 100546 with Ro-vibrational CO Emission Lines

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In this paper we present high resolution 4.7 μm spectra of the isolated Herbig Be star HD 100546. HD 100546 has been the subject of intense scrutiny because it is a young nearby star with a transitional disk. We observe the Δv=1 ro-vibrational CO transitions in order to clarify the distribution of warm gas in the inner disk. Modeling of the CO spectrum indicates that the gas is vibrationally excited by collisions and UV fluorescence. The observed emission extends from 13 - 100 AU. The inner edge of the molecular gas emission is consistent with the inner edge of the optically thick dust disk indicating that the inner hole is not simply a hole in the dust opacity but is likely cleared of gas as well. The rotational temperature of the CO is $\sim$1000K – much hotter than the $\sim$200K CO in the otherwise similar transitional disk surrounding HD 141569. The origin of this discrepancy is likely linked to the brighter PAH emission observed toward HD 100546. We use the excitation of the CO to constrain the geometry of the inner disk and comment on the evolutionary state of the system.

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X-Ray Variability of σ Orionis Young Stars as Observed with *ROSAT*

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We used the Aladin Virtual Observatory tool and High Resolution Imager *ROSAT* archival data to search for X-ray variability in scale of days in 23 young stars in the σ Orionis cluster and a background galaxy. Five stars displayed unambiguous flares and had probabilities $p_{var} >> 99\%$ of being actual variables. Two of the detected flares were violent and long lasting, with maximum duration of six days and amplitude of eight times above the quiescent level. We classified another four stars as possible X-ray variables, including the binary system formed by the B2Vp star σ Ori E and its close late-type companion. This makes a minimum frequency of high-amplitude X-ray variability in excess of a day of 39% among σ Orionis stars. The incidence of this kind of X-ray variability seems to be lower among classical T Tauri stars with mid-infrared flux excesses than among fast-rotating, disk-less young stars.

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Supersonic turbulence in the cold massive core JCMT 18354-0649S

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An example of a cold massive core, JCMT 18354-0649S, a possible high mass analogue to a low mass star forming core is studied. Line and continuum observations from JCMT, Mopra Telescope and *Spitzer* are presented and modelled in detail using a 3D molecular line radiative transfer code. In almost every way JCMT 18354-0649S is a scaled-up version of a typical low mass core with similar temperatures, chemical abundances and densities. The difference is that both the infall velocity and the turbulent width of the line profiles are an order of magnitude larger. While the higher infall velocity is expected due to the large mass of JCMT 18354-0649S, we suggest that the dissipation of this highly supersonic turbulence may lead to the creation of dense clumps of gas that surround the high mass core.

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The effects of Poisson noise on SPH calculations

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A simple algorithm is presented which generates a lattice-like, regular spacing of smoothed particle hydrodynamics (SPH) particles in discs, with any prescribed density gradient. Using this for comparison we demonstrate the effect of Poisson noise on SPH estimates of density, pressure and viscous forces when calculated using randomly distributed particles. The standard deviation of density and pressure is typically increased by greater than an order of magnitude. In a disc with a Keplerian velocity profile, the effectiveness of the Balsara switch in reducing the shear component of SPH artificial viscosity is greatly enhanced when the particles are properly spaced, reducing the magnitude of viscosity by two orders of magnitude. Noise problems are exacerbated, not removed, by increasing the numbers of SPH particles, if the number of neighbours used is kept constant. However, comparison of the evolution of a disc

created using perfectly spaced particles and a disc with identical parameters but randomly placed particles, reveals very similar results. Although there are subtle differences in the evolution, and the smooth disc takes longer to begin developing structure, in both cases the identical number of objects is created by gravitational collapse. SPH disc simulations do not depend on initial density disturbances to evolve objects by gravitational collapse, which gives added credence to the validity of the results. It also appears that complicated disc settling procedures are unnecessary.

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Warped Ionized Hydrogen in the Southern Hemisphere

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We report observations of the H166α (ν = 1424.734 MHz) radio recombination line (RRL) emission from the Galactic plane in the longitude range l = 267°-302° and latitude range b = ?30 to +15. The line emission observed describes the Carina arm in the Galactic azimuth range from θ = 260° to 190°. The structure is located at negative latitudes with respect to the formal Galactic plane. The observations are combined with RRL data from the first Galactic quadrant. Both quadrants show the signature of the warp for the ionized gas, but an asymmetry of the distribution is noted. In the fourth quadrant, the gas is located between Galactic radii R ≡ 7 and 10 kpc, and the amplitude of the warp is seen from the midplane to z ≡ 150 pc. In the first quadrant, the gas is found between R ≡ 8 and 13-16 kpc, and flares to z ≡ +350 pc. We confirm the warp of the ionized gas near the solar circle. The distribution of the ionized gas is compared with the maximum intensity HI emission ($0.30 < n_{HI} < 0.45$ cm^{-3}) at intervals of the Galactic ring. The ionized material is correlated with the HI maximum intensity in both quadrants, and both components show the same tilted behavior with respect to the mid-Galactic plane.

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An Adaptive Optics Survey For Close Protostellar Binaries

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In order to test the hypothesis that Class I protostellar binary stars are a product of ejections during the dynamical decay of non-hierarchical multiple systems, we combined the results of new adaptive optics (AO) observations of Class I protostars with our previously published AO data to investigate whether Class I protostars with a widely separated companion (r>200 AU) are more likely to also have a close companion (r<200 AU). In total, we observed 47 embedded young stellar objects (YSOs) with either the Subaru natural guide star AO system or the Keck laser guide star AO system. We found that targets with a widely separated companion within 5,000 AU are not more likely to have a close companion. However, targets with another YSO within a projected separation of 25,000 AU are much more likely to have a close companion. Most importantly, every target with a close companion has another YSO within a projected separation of 25,000 AU. We came to the same conclusions after considering a restricted sample of targets within 500 pc and close companions wider than 50 AU to minimize incompleteness effects. The Orion star forming region was found to have an excess of both close binaries and YSOs within 25,000 AU compared to other star forming regions. We interpret these observations as strong evidence that many close Class I binary stars form via ejections and that many of the ejected stars become unbound during the Class I phase.

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A Class I and Class II CH_3OH Maser Survey of Extended Green Objects (EGOs) from the GLIMPSE Survey

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We present the results of a high angular resolution Very Large Array (VLA) Class I 44 GHz and Class II 6.7 GHz CH_3OH maser survey of a sample of ∼20 massive young stellar object (MYSO) outflow candidates selected on the basis of extended 4.5 μm emission in *Spitzer* Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) images. These 4.5 μm-selected candidates are referred to as extended green objects (EGOs), for the common coding of this band as green in three-color IRAC images. The detection rate of 6.7 GHz Class II CH_3OH masers, which are associated exclusively with massive YSOs, towards EGOs is ≥64%–nearly double the detection rate of surveys using other MYSO selection criteria. The detection rate of Class I 44 GHz CH_3OH masers, which trace molecular outflows, is ∼89% towards EGOs associated with 6.7 GHz CH_3OH masers. The two types of CH_3OH masers exhibit different spatial distributions: 6.7 GHz masers are centrally concentrated and usually coincide with 24 μm emission, while 44 GHz masers are widely distributed and generally trace diffuse 4.5 μm features. We also present results of a complementary James Clerk Maxwell Telescope (JCMT) single-pointing molecular line survey of EGOs in the outflow tracers HCO^+(3-2) and SiO(5-4). The HCO^+ line profiles and high SiO detection rate (90%) are indicative of the presence of active outflows. No 44 GHz continuum emission is detected at the 5 mJy beam^{-1} (5σ) level towards 95% of EGOs surveyed, excluding bright ultracompact H II regions as powering sources for the 4.5 μm outflows. The results of our surveys constitute strong evidence that EGOs are young, massive YSOs, with active outflows, presumably powered by ongoing accretion.

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Rotational Structure and Outflow in the Infrared Dark Cloud 18223-3

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Aims. We examine an Infrared Dark Cloud at high spatial resolution as a means to study rotation, outflow, and infall at the onset of massive star formation.
Methods. The Infrared Dark Cloud (IRDC) 18223-3 was observed at 1.1 mm and 1.3 mm with the Submillimeter Array (SMA) and follow-up short spacing information was obtained with the IRAM 30 m telescope. Additional data were taken at 3 mm with the IRAM Plateau de Bure Interferometer (PdBI).
Results. Submillimeter Array observations combined with IRAM 30 meter data in ^{12}CO(2–1) reveal the outflow orientation in the IRDC 18223-3 region, and PdBI 3 mm observations confirm this orientation in other molecular species. The implication of the outflow's presence is that an accretion disk is feeding it, so using line data for high density tracers such as $C^{18}O$, N_2H^+, and CH_3OH, we looked for indications of a velocity gradient perpendicular to the outflow direction. Surprisingly, this gradient turns out to be most apparent in CH_3OH. The large size (28,000 AU) of the flattened rotating object detected indicates that this velocity gradient cannot be due solely to a disk, but rather from inward spiraling gas within which a Keplerian disk likely exists. The rotational signatures can be modeled via rotationally infalling gas. From the outflow parameters, we derive properties of the source such as an outflow dynamical age of ∼37,000 years, outflow mass of ∼13 $M_\odot$, and outflow energy of $\sim 1.7 \times 10^{46}$ erg. While the outflow mass and energy are clearly consistent with a high-mass star forming region, the outflow dynamical age indicates a slightly more evolved evolutionary stage than previous spectral energy distribution (SED) modeling indicates.
Conclusions. The orientation of the molecular outflow associated with IRDC 18223-3 is in the northwest-southeast direction and velocity gradients orthogonal to the outflow reveal a large rotating structure likely harboring an accretion disk within. We also present a model of the observed methanol velocity gradient. The calculated outflow properties reveal that this is truly a massive star in the making. These data present evidence for one of the youngest known

outflow/infall/disk systems in massive star formation. A tentative evolutionary picture for massive disks is discussed.

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Star and protoplanetary disk properties in Orion's suburbs

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Context. Knowledge of the evolution of circumstellar accretion disks is pivotal to our understanding of star and planet formation; and yet despite intensive theoretical and observational studies, the disk dissipation process is not well understood. Infrared observations of large numbers of young stars, as performed by the *Spitzer Space Telescope*, may advance our knowledge of this inherently complex process. While infrared data reveal the evolutionary status of the disk, they hold little information on the properties of the central star and the accretion characteristics.
Aims. Existing 2MASS and Spitzer archive data of the Lynds 1630N and 1641 clouds in the Orion GMC provide disk properties of a large number of young stars. We wish to complement these data with optical data that provide the physical stellar parameters and accretion characteristics.
Methods. We performed a large optical spectroscopic and photometric survey of the aforementioned clouds. Spectral types, as well as accretion and outflow characteristics, are derived from our VLT/VIMOS spectra. Optical SDSS and CAHA/LAICA imaging was combined with 2MASS, Spitzer IRAC, and MIPS imaging to obtain spectral energy distributions from 0.4 to 24 μm. Reddened model atmospheres were fitted to the optical/NIR photometric data, keeping $T_{\rm eff}$ fixed at the spectroscopic value. Mass and age estimates of individual objects were made through placement in the HR diagram and comparison to several sets of pre-main sequence evolutionary tracks.
Results. We provide a catalog of 132 confirmed young stars in L1630N and 267 such objects in L1641. We identify 28 transition disk systems, 20 of which were previously unknown, as well as 42 new transition disk candidates for which we have broad-band photometry but no optical spectroscopy. We give mass and age estimates for the individual stars, as well as equivalent widths of optical emission lines, the extinction, and measures of the evolutionary state of the circumstellar dusty disk. We estimate mass accretion rates $\dot{M}_{acc}$ from the equivalent widths of the Hα, Hβ, and He I 5876$\mathring{A}$ emission lines, and find a dependence of $\dot{M}_{acc} \propto M_*^{\alpha}$, with $\alpha \sim$3.1 in the subsolar mass range that we probe. An investigation of a large literature sample of mass accretion rate estimates yields a similar slope of $\alpha \sim$2.8 in the subsolar regime, but a shallower slope of $\alpha \sim$2.0 if the whole mass range of $0.04\,{\rm M}_\odot \leq M_* \leq 5\,{\rm M}_\odot$ is included. The fraction of stars with transition disks that show significant accretion activity is relatively low compared to stars with still optically thick disks (26±11% vs. 57±6%, respectively). However, those transition disks that *do* show significant accretion have the same median accretion rate as normal optically thick disks of $3\text{-}4\times10^{-9}{\rm M}_\odot{\rm yr}^{-1}$. Analyzing the age distribution of various populations, we find that the ages of the CTTSs and the WTTSs with disks are statistically indistinguishable, the WTTSs without disks are significantly older than the CTTSs, and the ages of the transition disks and the WTTSs without disks are statistically indistinguishable. These results argue against disk-binary interaction or gravitational instability as mechanisms causing a transition disk appearance. Our observations indicate that disk lifetimes in the clustered population are shorter than in the distributed population. In addition to the spectroscopic sample analyzed in this paper, we provide a photometric catalog of sources detected in the optical and infrared, but without spectroscopic observations. As judged by their infrared colors, many of these are YSO candidates. In our survey we identify 2 new aggregates in L1641. We find 4 apparently subluminous objects with extremely high equivalent widths of Hα and other emission lines, and 1 previously unknown FU Orionis object. We find that the low-density molecular cloud emission that surrounds the star-forming cores has significant substructure on scales of $\lesssim$0.2 pc in L1641 but not in L1630. We propose refined Hα equivalent width criteria to distinguish WTTSs from CTTSs in which the boundary EW is lowered significantly for late M spectral types.

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Linking Pre- and Proto-Stellar Objects in the Intermediate-/High-Mass Star Forming Region IRAS 05345+3157

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Context. To better understand the initial conditions of the high-mass star formation process, it is crucial to study at high angular resolution the morphology, the kinematics, and the interactions of the coldest condensations associated with intermediate-/high-mass star forming regions.
Aims. This paper studies the cold condensations in the intermediate-/high-mass proto-cluster IRAS 05345+3157, focusing on the interaction with the other objects in the cluster.
Methods. We performed millimeter high-angular resolution observations, both in the continuum and several molecular lines, with the PdBI and the SMA. In a recent paper, we published part of these data. The main finding of that work was the detection of two cold and dense gaseous condensations, called N and S (masses ~ 2 and $\sim 9\ M_{\odot}$), characterised by high values of deuterium fractionation (∼0.1 in both cores) obtained from the column density ratio $N(N_2D^+)/N(N_2H^+)$. In this paper, we present a full report of the observations, and a complete analysis of the data obtained.
Results. The millimeter maps reveal the presence of 3 cores inside the interferometer primary beam, called C1-a, C1-b and C2. None of them are associated with cores N and S. C1-b is very likely associated with a newly formed early-B ZAMS star embedded inside a hot core, while C1-a is more likely associated with a class 0 intermediate-mass protostar. The nature of C2 is unclear. Both C1-a and C1-b are good candidates as driving sources of a powerful ^{12}CO outflow, which strongly interacts with N, as demonstrated by the velocity gradient of the gas along this condensation. The N_2H^+ linewidths are between ~ 1 and 2 km s^{-1} in the region where the continuum cores are located, and smaller (∼0.5-1.5 km s^{-1}) towards N and S, indicating that the gas in the deuterated condensations is more quiescent than that associated with the continuum sources. This is consistent with the fact that they are still in the pre-stellar phase and hence the star formation process has not yet taken place there.
Conclusions. The study of the gas kinematics across the source indicates a tight interaction between deuterated condensations and the sources embedded in millimeter cores. For the nature of N and S, we propose two scenarios: they can be low-mass pre-stellar condensations or "seeds" of future high-mass star(s). However, from these data it is not possible to establish how the turbulence triggered by the neghbouring cluster of protostars can influence the evolution of the condensations.

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The Rotating Molecular Structures and the Ionized Outflow Associated with IRAS 16547-4247

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We present VLA 1.3 cm radio continuum and water maser observations as well as SMA SO_2 (226.300 GHz) and 1.3 mm dust continuum observations toward the massive star formation region IRAS 16547-4247. We find evidence of multiple sources in the central part of the region. There is evidence of a rotating structure associated with the most massive of these sources, traced at small scales (∼50 AU) by the water masers. At large scales (∼1000 AU) we find a velocity gradient in the SO_2 molecular emission with a barely resolved structure that can be modeled as a rotating ring or two separate objects. The velocity gradients of the masers and of the molecular emission have the same sense and may trace the same structure at different size scales. The position angles of the structures associated with the velocity gradients are roughly perpendicular to the outflow axis observed in radio continuum and several molecular tracers. We estimate the mass of the most massive central source to be around 30 solar masses from the velocity gradient in the water maser emission. The main source of error in this estimate is the radius of the rotating structure. We also find water masers that are associated with the large scale molecular outflow of the system, as well as water masers that are associated with other sources in the region. Our results suggest that the formation of this source, one of the most luminous protostars or protostellar clusters known, is taking place with the presence of ionized jets and disk-like structures

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Magnetic Fields in the Formation of Massive Stars

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Massive stars play a crucial role in the production of heavy elements and in the evolution of the interstellar medium, yet how they form is still a matter of debate. We report high-angular-resolution submillimeter observations toward the massive hot molecular core (HMC) in the high-mass star-forming region G31.41+0.31. We find that the evolution of the gravitational collapse of the HMC is controlled by the magnetic field. The HMC is simultaneously contracting and rotating, and the magnetic field lines threading the HMC are deformed along its major axis, acquiring an hourglass shape. The magnetic energy dominates over the centrifugal and turbulence energies, and there is evidence of magnetic braking in the contracting core.

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A spectroscopic survey of the youngest field stars in the solar neighbourhood. I. The optically bright sample

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Aims. We present the first results of an ambitious ground-based observation programme conducted on 1-4 meter class telescopes. Our sample consists of 1097 active and presumably young stars, all of them being optical (Tycho Catalogue) counterparts of ROSAT All-Sky Survey X-ray sources in the northern hemisphere. In this paper, we concentrate on the optically brightest ($V_{\rm T} \leq 9.5^m$) candidates (704 objects). We acquired high-resolution optical spectroscopy in the Hα and/or lithium spectral regions for 426 of such stars without relevant data in the literature. We describe the star sample and the observations and we start to discuss the physical properties of the investigated stars.
Methods. We used a cross-correlation technique and other tools developed by us to derive accurate radial and rotational velocities and to perform an automatic spectral classification for both single stars and double-lined systems. The spectral subtraction technique was used to derive chromospheric activity levels and lithium abundances. We estimated the fraction of young single stars and multiple systems in stellar soft X-ray surveys and the contamination by more evolved systems, like RS CVn binaries. We classified stars on the basis of their lithium abundance and give

a glimpse of their sky distribution.
Results. The sample appears to be a mixture of quite young Pleiades-like and Hyades-like stars plus an older lithium-poor population probably born within the last 1-2 Gyr. Seven stars with a lithium abundance compatible with the age of IC 2602 (about 30 Myr) or even younger were detected as well, although two appear to be lithium-rich giants.The discovery of a large number of highly or moderately lithium-rich giants is another outcome of the present survey.
Conclusions. The contamination of soft X-ray surveys by old systems in which the activity level is enhanced by tidal synchronisation is not negligible, especially for K-type stars. Five stars with lithium content close to the primordial abundance are probably associated with already known moving groups in the solar neighbourhood. Some of them are good post-T Tauri candidates according to their positions in the HR diagram.

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A *Spitzer* Survey of Young Stellar Clusters within One Kiloparsec of the Sun: Cluster Core Extraction and Basic Structural Analysis

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We present a uniform mid-infrared imaging and photometric survey of 36 young, nearby, star-forming clusters and groups using *Spitzer* IRAC and MIPS. We have confidently identified and classified 2548 young stellar objects using recently established mid-infrared color-based methods. We have devised and applied a new algorithm for the isolation of local surface density enhancements from point source distributions, enabling us to extract the overdense cores of the observed star forming regions for further analysis. We have compiled several basic structural measurements of these cluster cores from the data, such as mean surface densities of sources, cluster core radii, and aspect ratios, in order to characterize the ranges for these quantities. We find that a typical cluster core is 0.39 pc in radius, has 26 members with infrared excess in a ratio of Class II to Class I sources of 3.7, is embedded in a A_K=0.8 mag cloud clump, and has a surface density of 60 pc^{-2}. We examine the nearest neighbor distances among the YSOs in several ways, demonstrating similarity in the spacings between Class II and Class I sources but large member clusters appear more dense than smaller clusters. We demonstrate that near-uniform source spacings in cluster cores are common, suggesting that simple Jeans fragmentation of parsec-scale cloud clumps may be the dominant process governing star formation in nearby clusters and groups. Finally, we compare our results to other similar surveys in the literature and discuss potential biases in the data to guide further interpretation.

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Sigma Orionis IRS1 A and B: A Binary Containing a Proplyd

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We report optical and infrared imaging spectroscopy observations of the young binary object σ Orionis IRS1 A/B. The brighter component (σ Ori IRS1 A) of this binary system has M1 spectral type and a mass in the range of $\approx 0.3 - 0.8\ M_\odot$. The fainter component (σ Ori IRS1 B) has a unique morphology and spectrum. The unresolved stellar object is surrounded by an extended envelope that is slightly offset from the position of this star. The envelope's spectrum shows strong emission lines of H and HeI but no shock-excited emission from H_2 or [FeII]. The embedded stellar object σ Ori IRS1 B has an absorption spectrum characteristic of a late M photosphere, but with an additional

approximately equal amount of dust continuum flux veiling the absorption lines. σ Ori IRS1 B is probably a young brown dwarf embedded in a proplyd that is being photo-evaporated by the UV flux of the nearby multiple O and B star system σ Ori.

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Radiative Transfer in Circumstellar Disks I. 1D Models for GQ Lupi

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We present a new code for the calculation of the 1D structure and synthetic spectra of accretion disks. The code is an extension of the general purpose stellar atmosphere code PHOENIX and is therefore capable of including extensive lists of atomic and molecular lines as well as dust in the calculations. We assume that the average viscosity can be represented by a critical Reynolds number in a geometrically thin disk and solve the structure and radiative transfer equations for a number of disk rings in the vertical direction. The combination of these rings provides the total disk structure and spectrum. Since the warm inner regions of protoplanetary disks show a rich molecular spectrum, they are well suited for a spectral analysis with our models. In this paper we test our code by comparing our models with high-resolution VLT CRIRES spectra of the T Tauri star GQ Lup.

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The Earth-Moon system during the Late Heavy Bombardment period – geochemical support for impacts dominated by comets

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The solid planets assembled 4.57 Gyr ago during a period of less than 100 Myr, but the bulk of the impact craters we see on the inner planets formed much later, in a narrow time interval between 3.8 and 3.9 Gyr ago, during the so-called Late Heavy Bombardment (LHB). It is not certain what caused the LHB, and it has not been well known whether the impactors were comets or asteroids, but our present study lend support to the idea that it was comets. Due to the Earth's higher gravity, the impactors will have hit the Earth with ∼twice the energy density that they hit the Moon, and the bombardment will have continued on Earth longer than on the Moon. All solid surface of the Earth will have been completely covered with craters by the end of the LHB.

However, almost nothing of the Earth's crust from even the end of this epoch, is preserved today. One of the very few remnants, though, is exposed as the Isua greenstone belt (IGB) and nearby areas in Western Greenland. During a field expedition to Isua, we sampled three types of metasedimentary rocks, deposited ∼3.8 billion years ago, that contain information about the sedimentary river load from larger areas of surrounding land surfaces (mica-schist and turbidites) and of the contemporaneous seawater (BIF). Our samples show evidence of the LHB impacts that took place on Earth, by an average of a seven times enrichment (150 ppt) in iridium compared to present day ocean crust (20 ppt). The clastic sediments show slightly higher enrichment than the chemical sediments, which may be due to contamination from admixtures of mafic (proto-crustal) sources.

We show that this enrichment is in agreement with the lunar cratering rate and a corresponding extraterrestrial LHB contribution to the Earth's Hadean-Eoarchean crust, provided the bulk of the influx was cometary (i.e., of high velocity and low in CI abundance), but not if the impactors were meteorites (i.e. had velocities and abundances similar to present day Earth crossing asteroids). Our study is a first direct indication of the nature of the LHB impactors, and the first to find an agreement between the LHB lunar cratering rate and the Earth's early geochemical record (and the corresponding lunar record). The LHB comets that delivered the iridium we see at Isua will at the same time have delivered the equivalent of a ~1 km deep ocean, and we explain why one should expect a cometary ocean to become roughly the size of the Earth's present-day ocean, not only in terms of depth but also in terms of the surface area it covers. The total impacting mass on the Earth during the LHB will have been ~1000 t/m^2.

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Rotation and Outflow motions in the very low-mass Class 0 protostellar system HH 211 at subarcsecond resolution

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HH 211 is a nearby young protostellar system with a highly collimated jet. We have mapped it in 352 GHz continuum, SiO ($J = 8-7$), and HCO$^+$ ($J = 4-3$) emission at up to ~ 0.2" resolution with the Submillimeter Array (SMA). The continuum source is now resolved into two sources, SMM1 and SMM2, with a separation of ~ 84 AU. SMM1 is seen at the center of the jet, probably tracing a (inner) dusty disk around the protostar driving the jet. SMM2 is seen to the southwest of SMM1 and may trace an envelope-disk around a small binary companion. A flattened envelope-disk is seen in HCO$^+$ around SMM1 with a radius of ~ 80 AU perpendicular to the jet axis. Its velocity structure is consistent with a rotation motion and can be fitted with a Keplerian law that yields a mass of ~ 50±15 $M_{\rm Jup}$ (a mass of a brown dwarf) for the protostar. Thus, the protostar could be the lowest mass source known to have a collimated jet and a rotating flattened envelope-disk. A small-scale (~ 200 AU) low-speed (~ 2 km s^{-1}) outflow is seen in HCO$^+$ around the jet axis extending from the envelope-disk. It seems to rotate in the same direction as the envelope-disk and may carry away part of the angular momentum from the envelope-disk. The jet is seen in SiO close to ~ 100 AU from SMM1. It is seen with a "C-shaped" bending. It has a transverse width of $\lesssim$ 40 AU and a velocity of ~ 170±60 km s^{-1}. A possible velocity gradient is seen consistently across its innermost pair of knots, with ~ 0.5 km s^{-1} at ~ 10 AU, consistent with the sense of rotation of the envelope-disk. If this gradient is an upper limit of the true rotational gradient of the jet, then the jet carries away a very small amount of angular momentum of $\lesssim$ 5 AU km s^{-1} and thus must be launched from the very inner edge of the disk near the corotation radius.

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Mid-infrared interferometry of massive young stellar objects. I. VLTI and Subaru observations of the enigmatic object M8E-IR

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Our knowledge of the inner structure of embedded massive young stellar objects is still quite limited. Thus, it is difficult to decide to what extent the mass accumulation onto the forming massive star differs from the process of low-mass star formation. We attempt to overcome the spatial resolution limitations of conventional thermal infrared imaging. We employed mid-infrared interferometry using the MIDI instrument on the ESO/VLTI facility for investigating M8E-IR, a well-known massive young stellar object suspected of containing a circumstellar disk. Spectrally dispersed visibilities in the 8–13 μm range have been obtained at seven interferometric baselines. We resolve the mid-infrared emission of M8E-IR and find typical sizes of the emission regions of the order of 30 milliarcseconds ($\widehat{=}$ 45 AU). Radiative transfer simulations have been performed to interpret the data. The fitting of the spectral energy distribution, in combination with the measured visibilities, does not provide evidence for an extended circumstellar disk with sizes $\gtrsim$ 100 AU but requires the presence of an extended envelope. The data are not able to constrain the presence of a small-scale disk in addition to an envelope. In any case, the interferometry measurements indicate the existence of a strongly bloated, relatively cool central object, possibly tracing the recent accretion history of M8E-IR. In addition, we present 24.5 μm images that clearly distinguish between M8E-IR and the neighbouring ultracompact HII region and which show the cometary-shaped infrared morphology of the latter source.

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The Initial Mass Function of the Rich Young Cluster NGC 1818 in the Large Magellanic Cloud

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We use deep *Hubble Space Telescope* photometry of the rich, young (∼20- to 45-Myr old) star cluster NGC 1818 in the Large Magellanic Cloud to derive its stellar mass function (MF) down to $\sim 0.15\ M_\odot$. This represents the deepest robust MF thus far obtained for a stellar system in an extragalactic, low-metallicity ([Fe/H]∼ −0.4 dex) environment. Combining our results with the published MF for masses above 1.0 $M_\odot$, we obtain a complete present-day MF. This is a good representation of the cluster's initial MF (IMF), particularly at low masses, because our observations are centred on the cluster's uncrowded half-mass radius. Therefore, stellar and dynamical evolution of the cluster will not have affected the low-mass stars significantly. The NGC 1818 IMF is well described by both a lognormal and a broken power-law distribution with slopes of $\Gamma \sim 0.46 \pm 0.10$ and $\Gamma \sim -1.35$ (Salpeter-like) for masses in the range from 0.15 to 0.8 $M_\odot$ and greater than 0.8 $M_\odot$, respectively. Within the uncertainties, the NGC 1818 IMF is fully consistent with both the Kroupa solar neighbourhood and the Chabrier lognormal mass distributions.

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Too large and overlooked? Extended free-free emission towards massive star formation regions

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We present Australia Telescope Compact Array observations towards 6 massive star formation regions which, from their strong 24 GHz continuum emission but no compact 8 GHz continuum emission, appeared good candidates for hyper-compact HII regions. However, the properties of the ionised gas derived from the 19 to 93 GHz continuum emission and H70α + H57α radio recombination line data show the majority of these sources are, in fact, regions of spatially-extended, optically-thin free-free emission. These extended sources were missed in the previous 8 GHz observations due to a combination of spatial-filtering, poor surface brightness sensitivity and primary beam attenuation.

We consider the implications that a significant number of these extended HII regions may have been missed by previous surveys of massive star formation regions. If the original sample of 21 sources is representative of the population as a whole, the fact that 6 contain previously undetected extended free-free emission suggests a large number of regions have been mis-classified. Rather than being very young objects prior to UCHII region formation, they are, in fact, associated with extended HII regions and thus significantly older. In addition, inadvertently ignoring a potentially substantial flux contribution (up to ∼0.5Jy) from free-free emission has implications for dust masses derived from sub-mm flux densities. The large spatial scales probed by single-dish telescopes, which do not suffer from spatial filtering, are particularly susceptible and dust masses may be overestimated by up to a factor of ∼2.

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Ks-band (2.14μm) imaging of southern massive star formation regions traced by methanol masers

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We present deep, wide-field, Ks-band (2.14 μm) images towards 87 southern massive star formation regions traced by methanol maser emission. Using point-spread function fitting, we generate 2.14μm point source catalogues (PSCs) towards each of the regions. For the regions between $10^\circ < l < 350^\circ$ and $|b| <1$, we match the 2.14 μm sources with the GLIMPSE point source catalogue to generate a combined 2.14 to 8.0μm point source catalogue. We provide this data for the astronomical community to utilise in studies of the stellar content of embedded clusters.

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Binary Formation with Different Metallicities: Dependence on Initial Conditions

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The fragmentation process in collapsing clouds with various metallicities is studied using three-dimensional nested-grid hydrodynamics. Initial clouds are specified by three parameters: cloud metallicity, initial rotation energy and initial cloud shape. For different combinations of these parameters, we calculate 480 models in total and study cloud evolution, fragmentation conditions, orbital separation and binary frequency. For the cloud to fragment during collapse, the initial angular momentum must be higher than a threshold value, which decreases with decreasing metallicity. Although the exact fragmentation conditions depend also on the initial cloud shape, this dependence is only modest. Our results indicate a higher binary frequency in lower-metallicity gas. In particular, with the same median rotation parameter as in the solar neighbourhood, a majority of stars are born as members of binary/multiple systems for $< 10^{-4} Z_\odot$. With initial mass $< 0.1\,M_\odot$, if fragments are ejected in embryo from the host clouds by multi-body interaction, they evolve to substellar-mass objects. This provides a formation channel for low-mass stars in zero- or low-metallicity

environments.

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First Direct Simulation of Brown Dwarf Formation in a Compact Cloud Core

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Brown dwarf formation and star formation efficiency are studied using a nested grid simulation that covers five orders of magnitude in spatial scale (10^4–0.1 AU). Starting with a rotating magnetized compact cloud with a mass of $0.22\,M_\odot$, we follow the cloud evolution until the end of main accretion phase. Outflow of ~ 5 km/s emerges ~ 100 yr before the protostar formation and does not disappear until the end of the calculation. The mass accretion rate declines from $\sim 10^{-6}$ $M_\odot$/yr to $\sim 10^{-8}$–10^{-12} $M_\odot$/yr in a short time ($\sim 10^4$ yr) after the protostar formation. This is because (1) a large fraction of mass is ejected from the host cloud by the protostellar outflow and (2) the gas escapes from the host cloud by the thermal pressure. At the end of the calculation, 74% ($167M_{\rm Jup}$) of the total mass ($225M_{\rm Jup}$) is outflowing from the protostar, in which 34% ($77M_{\rm Jup}$) of the total mass is ejected by the protostellar outflow with supersonic velocity and 40% ($90M_{\rm Jup}$) escapes with subsonic velocity. On the other hand, 20% ($45M_{\rm Jup}$) is converted into the protostar and 6% ($13M_{\rm Jup}$) remains as the circumstellar disk. Thus, the star formation efficiency is $\epsilon = 0.2$. The resultant protostellar mass is in the mass range of brown dwarfs. Our results indicate that brown dwarfs can be formed in compact cores in the same manner as hydrogen-burning stars, and the magnetic field and protostellar outflow are essential in determining the star formation efficiency and stellar mass.

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Photometric and Polarimetric Clues to the Circumstellar Environment of RY Lupi

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Aims. We investigate the stellar and circumstellar properties of the bright southern T Tauri star RY Lup, a G-type star showing type III variability.
Methods. We report simultaneous BV polarimetric and UBV photometric observations obtained during 12 consecutive nights on the 1.0 m and 50 cm telescopes of the European Southern Observatory at La Silla. We compare these data to models.
Results. The polarization is high ($\sim$ 3.0%) when the star is faint and red ($V \sim 12.0$, $B-V \sim 13$), and it is low ($\sim$ 0.5%) when it is bright and bluer ($V \sim 11.0$, $B-V \sim 1.1$). The photometric and polarimetric variations share a common period of 3.75 d. Irregular light variations, larger at shorter wavelengths, are also superposed on the cyclic variations and may be due to processes different than the one producing the periodic variations. The linear polarization is produced by dust scattering in an asymmetric (flat) circumstellar envelope. The photometric and polarimetric variations can be explained with an almost edge-on circumstellar disk that is warped close to the star, where it interacts with the star's magnetosphere. The inhomogeneous disk matter contained in the warp corotates with the star and partially occults it during part of the rotation period, which explains the dips in luminosity and the

accompanying increase in polarization. All the information available on RY Lup is consistent with a system comprising a G8 star surrounded by an edge-on disk, and we find that the mass of RY Lup is $M_{\rm star}/M_{\odot} = 1.71 \pm 0.43$, while its age is $(1.2 \pm 0.4) \times 10^7$ yr.

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Chandra and *Spitzer* Observations Reveal New YSOs in the Heart of Trumpler 37

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We have discovered 22 new low-mass members in the center of the 4 Myr old open cluster Trumpler 37 (Tr 37) using archival *Chandra* and *Spitzer* data. Our use of the *Chandra* ACIS data and an improved reduction of *Spitzer* Infrared Array Camera data of the central region in Tr 37 led to the discovery of three new disk-bearing members, 19 new diskless members, and potentially 10 more infrared excess sources. Combining these new members with previous known members, we measured a disk frequency of ∼39%, which is lower than the previously reported disk frequency of ∼48%. Most of the new members are diskless stars that lie within 0.65 pc of the central massive O6.5V star HD 206267. The proximity of these sources to HD 206267 suggests photoevaporation may be accelerating disk evolution in the center of Tr 37. The new members have solar-type masses ranging from $\sim 0.6\ M_{\odot}$ to $1.8\ M_{\odot}$, spectral types ranging from late to early K, and X-ray luminosities in the range $29.3\ {\rm erg\ s^{-1}} \leq \log {\rm L\ X} \leq 31.9\ {\rm erg\ s^{-1}}$. The median X-ray luminosity ($L_X \sim 3 \times 10^{30}$ erg s^{-1}) of the new members in this intermediate-aged cluster is on the same level as younger (1-3 Myr) and slightly older (5 Myr) populations in the same mass range, which suggests the age-activity relation for pre-main-sequence solar-mass stars is constant up to ∼5 Myr and decays sometime thereafter.

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Evidence of triggered star formation in G327.3-0.6.
Dust-continuum mapping of an infrared dark cloud with P-ArTéMiS

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Aims. Expanding HII regions and propagating shocks are common in the environment of young high-mass star-forming complexes. They can compress a pre-existing molecular cloud and trigger the formation of dense cores. We investigate whether these phenomena can explain the formation of high-mass protostars within an infrared dark cloud located at the position of G327.3-0.6 in the Galactic plane, in between two large infrared bubbles and two HII regions.
Methods: The region of G327.3-0.6 was imaged at 450 μm with the CEA P-ArTéMiS bolometer array on the Atacama Pathfinder EXperiment telescope in Chile. APEX/LABOCA and APEX-2A, and Spitzer/IRAC and MIPS archives data were used in this study.
Results: Ten massive cores were detected in the P-ArTéMiS image, embedded within the infrared dark cloud seen in absorption at both 8 and 24 μm. Their luminosities and masses indicate that they form high-mass stars. The kinematical study of the region suggests that the infrared bubbles expand toward the infrared dark cloud.
Conclusions: Under the influence of expanding bubbles, star formation occurs in the infrared dark areas at the border of HII regions and infrared bubbles.

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The initial conditions of stellar protocluster formation. I. A catalogue of Spitzer dark clouds

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The majority of stars form in clusters. Therefore a comprehensive view of star formation requires understanding the initial conditions for cluster formation. The goal of our study is to shed light on the physical properties of infrared dark clouds (IRDCs) and the role they play in the formation of stellar clusters. This article, the first of a series dedicated to the study of IRDCs, describes techniques developed to establish a complete catalogue of Spitzer IRDCs in the Galaxy. We have analysed Spitzer GLIMPSE and MIPSGAL data to identify a complete sample of IRDCs in the region of Galactic longitude and latitude $10^\circ < |l| < 65^\circ$ and $|b| < 1^\circ$. From the 8μm observations we have constructed opacity maps and used a newly developed extraction algorithm to identify structures above a column density of $N_{H_2} = 1 \times 10^{22}$ cm^{-2}. The 24μm data are then used to characterize the star formation activity of each extracted cloud. A total of 11303 clouds have been extracted. A comparison with the existing MSX based catalogue of IRDCs shows that 80% of these Spitzer dark clouds were previously unknown. The algorithm also extracts $\sim$ 20000 to 50000 fragments within these clouds, depending on detection threshold used. A first look at the MIPSGAL data indicates that between 20% and 68% of these IRDCs show 24μm point-like association. This new database provides an important resource for future studies aiming to understand the initial conditions of star formation in the Galaxy.

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Inefficient star formation: The combined effects of magnetic fields and radiative feedback

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We investigate the effects of magnetic fields and radiative protostellar feedback on the star formation process using self-gravitating radiation magnetohydrodynamical calculations. We present results from a series of calculations of the collapse of 50 solar mass molecular clouds with various magnetic field strengths and with and without radiative transfer.
We find that both magnetic fields and radiation have a dramatic impact on star formation, though the two effects are in many ways complementary. Magnetic fields primarily provide support on large scales to low density gas, whereas radiation is found to strongly suppress small-scale fragmentation by increasing the temperature in the high-density material near the protostars. With strong magnetic fields and radiative feedback the net result is an inefficient star formation process with a star formation rate of $\sim<$ 10% per free-fall time that approaches the observed rate, although we have only been able to follow the calculations for $\sim$1/3 of a free-fall time beyond the onset of star formation.

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http://users.monash.edu.au/~dprice/pubs/mclusterRT/

Multi-generation massive star-formation in NGC 3576

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Context. Recent 1.2-mm continuum observations have shown the giant HII region NGC 3576 to be embedded in the centre of an extended filamentary dust-cloud. The bulk of the filament away from the HII region contains a number of clumps seen only at (sub-)millimetre wavelengths. Infrared and radio observations of the central star cluster have uncovered evidence of sequential star-formation leading us to believe that the adjacent clumps may host massive protostellar objects at a very early stage of evolution.
Aims. We have investigated the physical and chemical conditions in the dusty clumps with the goal of characterising their star-forming content.
Methods. We have used the Australia Telescope Compact Array (ATCA) to image the cloud for the NH_3 (1,1), (2,2) and (4,4) transitions, 22 GHz H_2O masers, and 23 GHz continuum emission. The 70-m Tidbinbilla dish was used to estimate the total integrated intensity of NH_3. We also utilised the 22-m Mopra antenna to map the region for the molecular lines ^{13}CO (1−0), $C^{18}O$ (1−0), HCO^+ (1−0), $H^{13}CO^+$ (1−0), CS (1−0) and N_2H^+ (1−0).
Results. Emission from dense molecular gas follows the morphology of the 1.2-mm dust emission, except towards the central ionised region. The HII region is observed to be expanding into the molecular cloud, sweeping up a clumpy shell of gas, while the central star cluster is dispersing the molecular gas to the east. Analysis of the NH_3 data indicates that temperature and linewidth gradients exist in the western arm of the filament. Temperatures are highest adjacent to the central HII region, indicating that the embedded cluster of young stars there is heating the gas. Six new H_2O masers were detected in the arms of the filament, all associated with NH_3 emission peaks, confirming that star-formation has begun within these cores. Core masses range from 5 to 516 $M_\odot$ and most appear to be gravitationally bound. Complementary results by André et al. (2008) imply that seven cores will go on to form massive stars between 15 and 50 $M_\odot$. The large scale velocity structure of the filament is smooth, but at least one clump shows the signature of inward gas motions via asymmetries in the NH_3 (1,1) line profiles. The same clump exhibits an enhanced abundance of N_2H^+, which coupled with an absence of CO indicates depletion onto the dust grain surface.
Conclusions. The HII region at the heart of NGC 3576 is potentially triggering the formation of massive stars in the bulk of the associated cloud.

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http://www.jb.man.ac.uk/∼cpurcell/downloads/2009-06-03_NGC3576.pdf

Spatially resolved mid-infrared observations of the triple system T Tauri

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The aim of this study is to enhance our knowledge of the characteristics and distribution of the circumstellar dust associated with the individual components of the young hierarchical triple system T Tau.
To reach this goal, observations in the N-band (8-13 μm) with the two-telescope interferometric instrument MIDI at

the VLTI were performed. For the northern component of the T Tau system, projected baseline lengths of 43 m, 62 m, and 85 m were used. For the southern binary projected baseline lengths of equivalent resolution could be utilised. Our study is based on both the interferometric and the spectrophotometric measurements and is supplemented by new visual and infrared photometry. Also, the phases were investigated to determine the dominating mid-infrared source in the close southern binary. The data were fit with the help of a sophisticated physical disc model. This model utilises the radiative transfer code MC3D that is based on the Monte-Carlo method.
Extended mid-infrared emission is found around all three components of the system. Simultaneous fits to the photometric and interferometric data confirm the picture of an almost face-on circumstellar disc around T Tau N. Towards this star, the silicate band is seen in emission. This emission feature is used to model the dust content of the circumstellar disc. Clear signs of dust processing are found. Towards T Tau S, the silicate band is seen in absorption. This absorption is strongly pronounced towards the infrared companion T Tau Sa as can be seen from the first individual N-band spectra for the two southern components. Our fits support the previous suggestion that an almost edge-on disc is present around T Tau Sa. This disc is thus misaligned with respect to the circumstellar disc around T Tau N. The interferometric data indicate that the disc around T Tau Sa is oriented in the north-south direction, which favours this source as launching site for the east-western jet. We further determine from the interferometric data the relative positions of the components of the southern binary in the N-band. We find good agreement with recent position measurements in the near-infrared.

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Substellar Objects in Nearby Young Clusters (SONYC): The bottom of the Initial Mass Function in NGC 1333

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SONYC – *Substellar Objects in Nearby Young Clusters* – is a survey program to investigate the frequency and properties of substellar objects with masses down to a few times that of Jupiter in nearby star-forming regions. Here we present the first results from SONYC observations of NGC 1333, a ~ 1 Myr old cluster in the Perseus star-forming complex. We have carried out extremely deep optical and near-infrared imaging in four bands (i', z', J, K) using Suprime-Cam and MOIRCS instruments at the Subaru telescope. The survey covers 0.25 sqdeg and reaches completeness limits of 24.7 mag in the i'-band and 20.8 mag in the J-band. We select 196 candidates with colors as expected for young, very low-mass objects. Follow-up multi-object spectroscopy with MOIRCS is presented for 53 objects. We confirm 19 objects as likely brown dwarfs in NGC 1333, seven of them previously known. Nine additional objects are classified as possible stellar cluster members, likely with early to mid M spectral types. The confirmed objects are strongly clustered around the peak in the gas distribution and the core of the cluster of known stellar members. For 11 of them, we confirm the presence of disks based on Spitzer/IRAC photometry. The effective temperatures for the brown dwarf sample range from 2500 K to 3000 K, which translates to masses of ~ 0.015 to $0.1\,M_{\odot}$, based on model evolutionary tracks. For comparison, the completeness limit of our survey translates to mass limits of $0.004\,M_{\odot}$ for $A_V < 5$ mag or $0.008\,M_{\odot}$ for $A_V < 10$ mag. Compared with other star-forming regions, NGC 1333 shows an overabundance of brown dwarfs relative to low-mass stars, by a factor of 2-5. On the other hand, NGC 1333 has a deficit of planetary-mass objects: Based on the surveys in σ Orionis, the Orion Nebula Cluster and Chamaeleon I, the expected number of planetary-mass objects in NGC 1333 is 8-10, but we find none. It is plausible that our survey has detected the minimum mass limit for star formation in this particular cluster, at around 0.012-0.02 $M_{\odot}$. If confirmed, our findings point to significant regional/environmental differences in the number of brown dwarfs and the minimum mass of the Initial Mass Function.

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Hot spots and a clumpy disk: Variability of brown dwarfs and stars in the young σ Ori cluster

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The properties of accretion disks around stars and brown dwarfs in the σ Ori cluster (age 3 Myr) are studied based on near-infrared time series photometry supported by mid-infrared spectral energy distributions. We monitor ~ 30 young low-mass sources over 8 nights in the J- and K-band using the duPont telescope at Las Campanas. We find three objects showing variability with J-band amplitudes ≥ 0.5 mag; five additional objects exhibit low-level variations. All three highly variable sources have been previously identified as highly variable; thus we establish the long-term nature of their flux changes. The lightcurves contain periodic components with timescales of $\sim 0.5 - 8$ days, but have additional irregular variations superimposed – the characteristic behaviour for classical T Tauri stars. Based on the colour variability, we conclude that hot spots are the dominant cause of the variations in two objects (#19 and #33), including one likely brown dwarf, with spot temperatures in the range of 6000-7000 K. For the third one (#2), a brown dwarf or very low mass star, inhomogenities at the inner edge of the disk are the likely origin of the variability. Based on mid-infrared data from Spitzer, we confirm that the three highly variable sources are surrounded by circum-(sub)-stellar disks. They show typical SEDs for T Tauri-like objects. Using SED models we infer an enhanced scaleheight in the disk for the object #2, which favours the detection of disk inhomogenities in lightcurves and is thus consistent with the information from variability. In the σ Ori cluster, about every fifth accreting low-mass object shows persistent high-level photometric variability. We demonstrate that estimates for fundamental parameters in such objects can be significantly improved by determining the extent and origin of the variations.

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Massive star formation and feedback in W49A: The source of our Galaxy's most luminous water maser outflow

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We present high spatial resolution mid-infrared (IR) images of the ring of ultracompact H II regions in W49A obtained at Gemini North, allowing us to identify the driving source of its powerful H_2O maser outflow. These data also confirm our previous report that several radio sources in the ring are undetected in the mid-IR because they are embedded deep inside the cloud core. We locate the source of the water maser outflow at the position of the compact mid-IR peak of source G (source G:IRS1) to within 0.07 arcsec. This IR source is not coincident with any identified compact radio continuum source, but is coincident with a hot molecular core, so we propose that G:IRS1 is a hot core driving an outflow analogous to the wide-angle bipolar outflow in OMC-1. G:IRS1 is at the origin of a larger bipolar cavity and CO outflow. The water maser outflow is orthogonal to the bipolar CO cavity, so the masers probably reside near its waist in the thin cavity walls. Models of the IR emission require a massive protostar with $M_* \simeq 45\ M_\odot$, $L_* \simeq 3\times10^5$ $L_\odot$, and an effective envelope accretion rate of $\sim 10^{-3}\ M_\odot\ \mathrm{yr}^{-1}$. Feedback from the central star could potentially drive

the small-scale H_2O maser outflow, but it has insufficient radiative momentum to have driven the large-scale bipolar CO outflow, requiring that this massive star had an active accretion disk over the past 10^4 yr. Combined with the spatialy resolved morphology in IR images, G:IRS1 in W49 provides compelling evidence for a massive protostar that formed by accreting from a disk, accompanied by a bipolar outflow.

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A Chandra and Spitzer census of the young star cluster in the reflection nebula NGC 7129

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The reflection nebula NGC 7129 has long been known to be a site of recent star formation as evidenced, e.g., by the presence of deeply embedded protostars and HH objects. However, studies of the stellar population produced in the star formation process have remained rudimentary. A major step forward was made with recent Spitzer imaging of the region. We make use of X-ray and IR imaging observations to identify the pre-main sequence stars in NGC 7129. Our study represents the next step towards a systematic assessment of the pre-main sequence population in NGC 7129. Completeness of the pre-main sequence sample is necessary for studying key features that allow to understand the star forming process, such as disk evolution, dynamical evolution and mass function. At a presumed age of $\sim$ 3 Myr, NGC 7129 is in the critical range where disks around young stars disappear. We define a sample of Young Stellar Objects based on color-color diagrams composed from IR photometry between 1.6 and 8 μm, from 2 MASS and Spitzer, and based on X-ray detected sources from a Chandra observation. This sample is composed of 26 Class II and 25 Class III candidates. It has been selected from infrared sources in the Chandra field (287 objects with photometry in all four Spitzer/IRAC bands, 811 objects with near-IR photometry) and the 59 X-ray sources detected with Chandra. The sample is estimated to be complete down to $\sim 0.5\,M_\odot$. The most restricted and least biased sub-sample of pre-main sequence stars is composed of lightly absorbed ($A_V < 5$ mag) stars in the cluster core. This sample comprises 7 Class II and 14 Class III sources, it has a disk fraction of 33^{+24}_{-19} %, and a median X-ray luminosity of $\log L_x$ [erg/s] = 30.3. Despite the various uncertainties related to the sample selection, absorption, mass distribution, distance and, consequently, the computation of disk fraction and X-ray luminosities, the data yield consistent results. In particular, we confirm the age of $\sim$ 3 Myr for the NGC 7129 cluster. The derived disk fraction is similar to that of σ Orionis, smaller than that of Cha I ($\sim$ 2 Myr), and larger than that of Upper Sco (5 Myr). The X-ray luminosity function is similar to that of NGC 2264 (2 Myr) but fainter than that of the Orion Nebula Cluster (1 Myr).

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http://www.astropa.unipa.it/∼stelzer/publications.html

Vertical structure of debris discs

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The vertical thickness of debris discs is often used as a measure of these systems' dynamical excitation and as clues to the presence of hidden massive perturbers such as planetary embryos. However, this argument could be flawed because the observed dust should be naturally placed on inclined orbits by the combined effect of radiation pressure and mutual collisions. We critically reinvestigate this issue and numerically estimate what the "natural" vertical thickness of a collisionally evolving disc is, in the absence of any additional perturbing body. We use a deterministic collisional code, following the dynamical evolution of a population of indestructible test grains suffering mutual inelastic impacts. Grain differential sizes as well as the effect of radiation pressure are taken into account. We find that, under the coupled effect of radiation pressure and collisions, grains naturally acquire inclinations of a few degrees. The disc is stratified with respect to grain sizes, with the smallest grains having the largest vertical dispersion and the bigger ones clustered

closer to the midplane. Debris discs should have a minimum "natural" observed aspect ratio $h_{min} \sim 0.04 \pm 0.02$ at visible to mid-IR wavelengths where the flux is dominated by the smallest bound grains. These values are comparable to the estimated thicknesses of many vertically resolved debris discs, as is illustrated with the specific example of AU Mic. For all systems with $h \sim h_{min}$, the presence (or absence) of embedded perturbing bodies cannot be inferred from the vertical dispersion of the disc

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Accretion disks around massive stars: Hydrodynamic structure, stability and dust sublimation

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We investigate the structure of accretion disks around massive protostar applying steady state models of thin disks. The thin disk equations are solved with proper opacity for dust and gas taking into account the huge temperature variation along the disk. We explore a wide parameter range concerning stellar mass, accretion rate, and viscosity parameter α. The most essential finding is a very high temperature of the inner disk. For e.g. a $10\,\mathrm{M}_\odot$ protostar and an accretion rate of $\sim 10^{-4}\,\mathrm{M}_\odot \mathrm{yr}^{-1}$, the disk midplane temperature may reach almost 10^5 K. The disk luminosity in this case is about $10^4\,\mathrm{L}_\odot$ and, thus, potentially higher than that of a massive protostar. We motivate our disk model with similarly hot disks around compact stars. We calculate a dust sublimation radius by turbulent disk self-heating of more than 10 AU, a radius, which is 3 times larger than caused by stellar irradiation. We discuss implications of this result on the flashlight effect and the consequences for the radiation pressure of the central star. In difference to disks around low mass protostars our models suggest rather high values for the disk turbulence parameter $\alpha \leq 1$. However, disk stability to fragmentation due to thermal effects and gravitational instability would require a lower α value. For $\alpha = 0.1$ we find stable disks out to 80 AU. Essentially, our model allows to compare the outer disk to some of the observed massive protostellar disk sources, and from that, extrapolate on the disk structure close to the star which is yet impossible to observe.

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http://adsabs.harvard.edu/abs/2009arXiv0906.5493V

The photodissociation and chemistry of CO isotopologues: applications to interstellar clouds and circumstellar disks

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Aims. Photodissociation by UV light is an important destruction mechanism for carbon monoxide (CO) in many astrophysical environments, ranging from interstellar clouds to protoplanetary disks. The aim of this work is to gain a better understanding of the depth dependence and isotope-selective nature of this process.
Methods. We present a photodissociation model based on recent spectroscopic data from the literature, which allows us to compute depth-dependent and isotope-selective photodissociation rates at higher accuracy than in previous work. The model includes self-shielding, mutual shielding and shielding by atomic and molecular hydrogen, and it is the first such model to include the rare isotopologues $\mathrm{C}^{17}\mathrm{O}$ and $^{13}\mathrm{C}^{17}\mathrm{O}$. We couple it to a simple chemical network to analyse CO abundances in diffuse and translucent clouds, photon-dominated regions, and circumstellar disks.
Results. The photodissociation rate in the unattenuated interstellar radiation field is 2.6×10^{-10} s^{-1}, 30% higher than currently adopted values. Increasing the excitation temperature or the Doppler width can reduce the photodissociation rates and the isotopic selectivity by as much as a factor of three for temperatures above 100 K. The model reproduces column densities observed towards diffuse clouds and PDRs, and it offers an explanation for both the enhanced and the reduced $N(^{12}\mathrm{CO})/N(^{13}\mathrm{CO})$ ratios seen in diffuse clouds. The photodissociation of $\mathrm{C}^{17}\mathrm{O}$ and $^{13}\mathrm{C}^{17}\mathrm{O}$ shows almost

exactly the same depth dependence as that of $C^{18}O$ and $^{13}C^{18}O$, respectively, so ^{17}O and ^{18}O are equally fractionated with respect to ^{16}O. This supports the recent hypothesis that CO photodissociation in the solar nebula is responsible for the anomalous ^{17}O and ^{18}O abundances in meteorites. Grain growth in circumstellar disks can enhance the $N(^{12}CO)/N(C^{17}O)$ and $N(^{12}CO)/N(C^{18}O)$ ratios by a factor of ten relative to the initial isotopic abundances.

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http://arxiv.org/abs/0906.3699

Molecular Gas and a New Young Stellar Cluster in the Far Outer Galaxy

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Aims. We investigate the star-formation ocurring in the region towards IRAS 07527-3446 in the molecular cloud [MAB97]250.63-3.63, in the far outer Galaxy. We report the discovery of a new young stellar cluster, and describe its properties and those of its parent molecular cloud.
Methods. Near-infrared JHK_S images were obtained with VLT/ISAAC, and millimetre line CO spectra were obtained with the SEST telescope. VLA archive date were also used.
Results. The cloud and cluster are located at a distance of 10.3 kpc and a Galactocentric distance of 15.4 kpc, in the far outer Galaxy. Morphologically, IRAS 07527-3446 appears as a young embedded cluster of a few hundred stars seen towards the position of the IRAS source, extending for about 2-4 pc and exhibiting sub-clustering. The cluster contains low and intermediate-mass young reddened stars, a large fraction having cleared the inner regions of their circumstellar discs responsible for $(H - K_S)$ colour excess. The observations are compatible with a $\leq$5 Myr cluster with variable spatial extinction of between $A_V = 5$ and $A_V = 11$. Decomposition of CO emission in clumps, reveals a clump clearly associated with the cluster position, of mass $3.3 \times 10^3\ M_\odot$. Estimates of the slopes of the K_S-band luminosity function and of the star-formation efficiency yield values similar to those seen in nearby star-formation sites. These findings reinforce previous results that the distant outer Galaxy continues to be active in the production of new and rich stellar clusters, with the physical conditions required for the formation of rich clusters continuing to be met in the very distant environment of the outer Galactic disc.

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Observations and Radiative Transfer Models of Molecular Outflows from Low and High Mass Star Forming Clouds

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Ph.D dissertation directed by: Dr M. P. Redman

Ph.D degree awarded: June 2009

The formation of a high mass star is a rapid and energetic process compared with low mass star formation. However the intricate details of high mass star formation are not known to the same degree. This is a major problem because high mass stars have a significant impact on the surrounding environment due to their prodigious ionising luminosity.

In this thesis the formation of high mass stars is investigated and compared with low mass star formation. This is carried out through observations and radiative transfer modelling of molecular line emission. A model which addresses all elements of high mass star formation has not been fully developed to date. This work seeks to extend some of the aspects of low mass star formation to high mass star formation particularly at the early stage of evolution of high mass protostellar cores.

The formation of low mass stars begins with the gravitational collapse of an interstellar cloud composed of gas molecules and dust grains. This leads to the formation of a cold ($T \approx 10$ K), dense ($n_{\mathrm{H}_2} \approx 10^6$ cm^{-3}) protostellar core; surrounding the core is an envelope. In both regions molecular material can freeze-out onto dust grains. Gravitationally collapsing material conserves the angular momentum in the core which can lead to core spin-up and break-up. However bipolar jets have been observed at the sites of star formation and are thought to be the mechanism that removes excess angular momentum. The jet interacts with the surrounding envelope by shock heating frozen material. When this happens the ice layers are vaporized and the molecular material is returned to the gas phase.

If the formation process is similar in cores forming high mass stars then infalling molecular gas should be detectable. Also one of the manifestations of the accretion process is bipolar molecular outflows. Both of these dynamic processes affect line emission observations of molecular gas. Therefore comparing the line emission from protostellar cores forming low and high mass stars can constrain the similarities and differences between the two modes of star formation.

This is carried out by observing line emission from different molecular gas species with the James Clerk Maxwell Telescope and the MOPRA telescope. Each species trace disparate physical conditions such as the cold dense core, the surrounding molecular envelope and the warm molecular outflow. The line emission profiles are compared with line profiles generated using a 3-D molecular line radiative transfer code. Fitting the observed emission line profiles allows us to construct a consistent model of the molecular gas in each core and in turn compare the model of low and high mass star forming cores.

Our principal findings are that the line profiles of infalling gas are fit with a model where the infall velocity and turbulent velocity are an order of magnitude higher in the high mass core than the low mass cores. The line profiles of optically thick species show evidence of an outflow in both types of cores. Our finding that high and low mass star formation proceed in a similar fashion agrees with recent observations of accretion disks and outflows in high mass cores indicating that many processes are shared between them. Modelling the molecular line emission using a radiative transfer code is a powerful technique to separate the contribution each component (core, envelope, outflow) makes to a line profile. These components have separate complex processes (infall, freeze-out, outflow and evaporation) occurring simultaneously and this work will lead to a better understanding of the complex interplay between them.

The Evolution of Dusty Disks Around Low-Mass Pre-Main Sequence Stars

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The evolution of protoplanetary disks is intricately tied to the origin of planets. The details of how these disks evolve from initially well-mixed distributions of gas and dust into systems composed mostly of rocky planets and gas giants like our own solar system is not well understood and is a fundamental question in astronomy. It is widely accepted that dust grain growth and settling to the disk midplane play an integral part in creating the planetesimals that amalgamate into planets. Newly formed planets will then interact with the disk, clearing the material around themselves and creating gaps. To get a more complete view of planet formation one should therefore study the observational signatures of dust growth, settling, and clearing in disks.

Here we present simulated spectral energy distributions of disks around low-mass classical T Tauri stars of various masses, accretion rates, inclinations, grain sizes, dust compositions, and amounts of settling. We find that the majority of observed disks lie within the parameter space probed by the models and are therefore "full disks." However, some disks have spectral energy distributions that cannot be explained by the full disk models. Some of these disks have a significant deficit of flux in the near- and mid-infrared but show substantial emission beyond 20 μm, similar to what is seen in full disks, indicating that the hot, inner regions of these "transitional disks" have undergone significant dust clearing. Here we model the transitional disks of CS Cha and CVSO 224. CS Cha is located in the ∼2 Myr old Chamaeleon star–forming region. We show it has an optically thick circumstellar disk inwardly truncated at ∼43 AU with some small, optically thin dust within the innermost 1 AU of its inner disk hole. CS Cha also has large grains and a more settled outer disk suggesting that it is in an advanced state of dust evolution. CVSO 224 is the only transitional disk located within the ∼10 Myr old 25 Orionis group in Orion OB1a. We find a ∼7 AU inner disk hole that contains a small amount of optically thin dust and measure an accretion rate of 7×10^{-11} $M_\odot$ yr^{-1} in this object, making it one of the slowest accreting transitional disks detected so far.

We also present evidence for a new class of disk: the pre-transitional disks. These disks have significant near-infrared excesses (2 – 5 μm), similar to what is seen in full disks, which indicates the presence of an optically thick inner disk. However, these pre-transitional disks also have a deficit of flux in the mid-infrared (5 – 20 μm) and significant emission at longer wavelengths, similar to transitional disks. This points to a gap within the disk rather than an inner disk hole. The pre-transitional disks around UX Tau A and LkCa 15 have gaps of 56 and 46 AU respectively. UX Tau A's gap is devoid of small grains while LkCa 15 has some small optically thin dust within its gap. We analyze near-infrared spectra between 2–5 μm for LkCa 15 and UX Tau A and demonstrate that the near-IR excess of both can be fit with a single-temperature blackbody at the dust destruction temperature. This indicates that the near-infrared excesses of LkCa 15 and UX Tau A originate from the wall of an optically thick inner disk at the dust destruction radius, independently confirming that these disks have gaps within their dust distributions.

This study of disks around pre-main sequence stars contributes new details on dust evolution. We report a range of grain sizes, settling, and inner disk hole radii in transitional disks as well as newly identified disks with gaps in their dust distributions. Our model grid of simulated disk SEDs also reveals that some observed disks in Taurus, Chamaeleon, and Ophiuchus cannot be explained by full disk models and are not known to be transitional or pre-transitional disks. We propose that these objects are pre-transitional disks with smaller gaps than previously observed, emphasizing that much still remains to be understood regarding the dust component of disks.

http://www.astro.lsa.umich.edu/∼ccespa/thesis.html

Post doc and Ph.D. positions at University of Copenhagen: Observations of the Earliest Stages of Low-Mass Star Formation

One graduate and one post doc position are available at the newly started "Center for Stars and Planets" - an initiative between the Natural History Museum of Denmark and the Niels Bohr Institute at University of Copenhagen, focusing on the origin and evolution of stars and planets. The successful candidates will be part of a research group led by Dr. Jes Jørgensen dedicated to studies of the earliest stages of low-mass star formation.

We are looking for two enthusiastic candidates with a particular interest in observations of star forming regions. The topic for the Ph.D. student will be the importance of outflows and shocks for the physical and chemical structure of the envelopes around low-mass protostars, in particular using data from the Herschel Space Observatory open time key program "Dust, Ice and Gas in Time (DIGIT)" and the Submillimeter Array key program, "Protostellar Submillimeter Array Campaign (PROSAC)" . The post doc will be involved in work with data from these large programs as well - and furthermore carry out an independent research program in collaboration with other members of the group. Both candidates will have good opportunities in helping to define and carrying out programs using facilities available to Danish astronomers (e.g., through ESO and ESA), which includes the Atacama Large Millimeter Array (ALMA) - currently expected to begin early science observations in 2011.

The positions are open for candidates of all nationalities. For both positions, experience in infrared/submillimeter observations and/or radiative transfer modeling is a plus. For the graduate position, a Master's degree in astronomy, physics or equivalent is required. For the post doc position, the candidate should have finished his/her doctoral thesis before taking up the position. Both positions are for three years - and is in the case of the graduate position expected to lead to a Ph.D. degree at University of Copenhagen. Currently, starting salaries are about 29,330 DKK (3,940 Euro) per month for Ph.D. students and 36,750 DKK (4,937 Euro) per month for post docs before tax and pension contributions. Salaries depend on seniority, as agreed between the Ministry of Finance and the Danish Confederation of Professional Associations. Note for the post doc position: non-Danish and Danish candidates who have lived abroad for an extended period of time before taking up a position, may be eligible for tax reductions. The positions carry the full benefits in terms of enrollment in the public Danish health care system. The University of Copenhagen wishes to reflect the surrounding society and encourage all qualified applicants regardless of personal background to apply for the positions.

For the Ph.D. position, the application should contain a curriculum vitae (including a certified list of university courses and grades), a statement of research experience and interests. The application should include the names and E-mail addresses of two academic referees familiar with the work of the applicant.

For the post doc position, the application should contain a curriculum vitae, a list of publications, a statement of research experience and plans. In addition, the applicant should arrange for three letters of references sent separately.

Review of applications will start on September 1 and continue until the positions have been filled. Requests for further information as well as applications and reference letters should be sent per E-mail (preferred) or regular mail to:

Dr. Jes Jørgensen (jes *at* snm.ku.dk)
Center for Star and Planet Formation, Natural History Museum of Denmark
Øster Voldgade 5-7
DK-1350 København K, Denmark

Post Doctoral Positions (3 year) in Star Formation

The Center for Astrophysics at the University of Porto (CAUP) accepts applications for post-doctoral positions in the area of star and planet formation. The fellowships are offered by the ministry of science and technology, have a duration of three years, renewable to a second term. The grants are expected to start by January 2010. Pre-applications to the Center of Astrophysics must be made by 20th July 2009. Short listed candidates will then submit the full application to the ministry by 1st September 2009.

The candidates must have submitted their thesis (not necessary to have a degree awarded) before 1st September 2009. Candidates are expected to carry independent research in the area of star formation and/or collaborate with researchers at CAUP. Research interests at CAUP focus in massive star formation, embedded clusters, outflows, jets and extrasolar planets with an emphasis on infrared and millimeter observations. CAUP offers excellent working conditions and has access to all ESO observing facilities. For further details or expression of interest contact Dr. Nanda Kumar (nanda *at* astro.up.pt) or Prof. Mario Monteiro (mjm *at* astro.up.pt)

Postdoctoral Position for Herschel Key Programmes at NAOC, Beijing

With its 3.5 m Cassegrain telescope and state-of-the-art instruments, ESA's Herschel Space Observatory will perform photometry and spectroscopy in the 57-670 m range. National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) has been actively contributing to Herschel/SPIRE since 2005 and is a formal partner of Herschel/SPIRE. Professors Maohai Huang and Jinzeng Li of the NAOC collaborative team are Associate Scientists of the Herschel/SPIRE Science Team. For detailed information on Herschel and the NAOC team, please refer to http://herschel.esac.esa.int/ and http://earth.bao.ac.cn/herschel/forums/.

Applications are invited for a postdoctoral position at NAOC, in Beijing, China, with an expected starting date of October 1, 2009. The successful applicant is expected to carry out one of the following fields of research: 1) HII regions and Photodissociation Regions (PDRs) property study and modeling, or 2) the mass loss history of evolved stars in predominantly the AGB, post-AGB, proto-PN and PN phases of evolution. The studies are based on two Guaranteed Time Key Projects (Gould-Belt and HOBYS) and one Open Time Key Project (Hi-Gal) of Herschel/SPIRE, which we have preferential data rights and publication rights. In particular, the applicant should take an active role in Hi-Gal, which will map the -60? ¡l¡ 60? portion of the Galactic Plane in five photometric bands between 60 and 600 m. Novel approaches for science analysis using cross-facility data will be encouraged.

The position is available for a period of three years, conditional to a positive evaluation of the research activity carried out during the first year and research progress in the following years. The gross yearly salary will be in the range RMB 40,000 - 84,000, adjustable depending on the capability and research experience of the candidate.

Potential candidates should have obtained a Ph.D. in Astrophysics obtained less than a year before application if applying for a first-term postdoctoral position. Preference is given to applicants under 40 years of age with proficiency in English and the ability in conducting independent scientific research in related fields. Experiences and expertise in mapping observations, large-scale surveys, space missions, infrared and/or sub-millimeter and Radio Recombination Line data processing, and numeric modeling of spatially distributed photo-chemical networks will be an asset.

Applications should include a Curriculum Vitae, a list of publications, and a statement of research interests. Applicants should also arrange for three letters of references to be sent independently. Applications sent in before 30 August 2009 will receive full consideration, and the post will be available till it is filled. Applications and inquiries should be sent to ljz *at* bao.ac.cn or mailed to: Prof. Jinzeng Li, National Astronomical Observatories, 20A Datun Road, Chaoyang District, Beijing 100012, China

Postdoctoral Research Scientist

The Kapteyn Astronomical Institute in Groningen, The Netherlands, invites applications for a postdoctoral research scientist. The successful candidate will mainly work on Herschel/PACS data. He or she is expected to actively participate in the PACS data analysis and to carry out related research. The candidate will be given the opportunity to pursue independent astrophysical research and to collaborate within Herschel Key Program teams.

The postdoctoral research scientist will encounter a stimulating scientific environment being in the same building as SRON, the PI institute and Instrument Control Center for the HIFI instrument. Staff from the Kapteyn Astronomical Institute and SRON are involved in many galactic and extragalactic Herschel Key Programs such as GASPS ("Gas Evolution in Protoplanetary Systems", PI: Dent), WISH ("Water In Star-forming regions with Herschel", PI: van Dishoeck), HS3F ("HIFI Spectral Surveys of Star Forming Regions", PI: Ceccarelli), WADI ("The warm and dense ISM", PI: Ossenkopf), HEXOS ("Herschel/HIFI Observations of EXtraOrdinary Sources: The Orion and Sagittarius B2 Starforming Regions", PI: Bergin), HERCULES ("A Herschel survey of molecular lines in (U)LIRGs: physical conditions, the nature of the power source, and a benchmark for high-z observations", PI: van der Werf). Thus, there is an exciting range of opportunities to establish new collaborations.

Interested applicants should have a PhD in astrophysics or physics and proven experience in far-infrared observations, including analysis of line data and good knowledge of (molecular) spectroscopy. The ability to work in an international team and a good command of the English language are essential. Experience with the Herschel/PACS instrument and knowledge of the Python/Jython scripting language are considered an asset.

The University of Groningen offers a salary dependent on qualifications and work experience up to a maximum of EUR 4374 (scale 11) gross per month for a full-time position. The duration of the contract is 2 years with a possible extension to a third year.

Interested candidates should send application material, including a curriculum vitae, a brief statement of past research and future plans, and arrange for three letters of reference to be sent to Dr. Inga Kamp, Kapteyn Astronomical Institute, P.O. Box 800, 9700 AV Groningen, The Netherlands (E-mail address: kamp astro.rug.nl). Selection of candidates will start **September 15, 2009**, and will continue until the position is filled.

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

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each issue of the newsletter. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/star-formation/index.cfm
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The Star Formation Newsletter is available on the World Wide Web at http://www.ifa.hawaii.edu/users/reipurth/newsletter.htm.

The Birth and Influence of Massive Stars
Prague 14 - 17 September 2009
CONSTELLATION Work Package 2 - Interim Meeting

The Birth and Influence of Massive Stars is the subject of the Marie Curie Research Training Network CONSTELLATION (MCRTN-CT-2006-035890). It is an important area of astrophysics joining three interconnected sub-topics:

1. The initial conditions for massive star formation;
2. The influence of the environment on massive star formation;
3. Feedback from massive stars.

Star formation scenarios based on turbulent fragmentation, protostellar feedback, or competitive accretion are explored.

A detailed picture of massive star formation in the Milky Way available through radio interferometers, ground-based optical/IR imaging systems, IR space telescopes and X-ray astronomical satellites, is compared with state-of-the-art numerical models of the massive star formation process. Analytical solutions are provided, in some cases helping to disentangle physical processes in the game. We investigate the initial conditions in the dark clouds - extremely dense, massive molecular cloud cores forming massive stars and massive star clusters. Direct measurements of the environment provide important insight into their formation mechanism. Mechanical and radiatively-driven feedback by winds and ionisation affect the surroundings of massive stars, forming expanding shells, unbinding stellar clusters and triggering secondary star formation in compressed layers.

This interim meeting of Work Package 2 of the CONSTELLATION network will review the above aspects of massive star formation and showcase the progress made over the past more than two years of cooperation.

Due to the capacity of the venue, we are limited to 50 participants. The places will be allocated on a first-come, first-served basis.

Further information:
`http://galaxy.ig.cas.cz/~richard/0909-prague`.

Ian Bonnell Jan Palous Ant Whitworth

The 1.1 mm Bolocam Galactic Plane Survey is Available

John Bally[1] and the BGPS team

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E-mail contact: John.Bally *at* colorado.edu

The Bolocam Galactic Plane Survey (BGPS) covers 170 square degrees of the northern Galactic Plane at a wavelength of 1.1 mm in the dust continuum. The survey was obtained with the 144 element Bolocam camera on the 10.4 meter diameter sub-mm telescope at the Caltech Submillimeter Observatory.

The survey team is pleased to announce the release of the survey data and source catalog through the NASA/IPAC Infrared Science Archive (IRSA) at the Infrared Processing and Analysis Center (IPAC):

http://irsa.ipac.caltech.edu/data/BOLOCAM_GPS/

Millimeter-wavelength thermal dust emission traces the densest molecular gas most directly associated with the birth of stars and star clusters. BGPS probes a range of scales from cores in nearby clouds destined to produce individual stars and more distant clumps which may give birth to massive stars and star clusters. It will enable the investigation of the initial conditions of massive star and cluster formation without the biases inherent in source selection based on embedded infrared sources, HII regions, masers, or other signposts of on-going star formation. The BGPS images and catalog provide an important database for future sub/millimeter observations with APEX, SMA, CARMA, the Herschel Space Observatory, ALMA, SCUBA-2, and other facilities.

The BGPS with an effective resolution of 33" FWHM provides contiguous coverage from $-10.5 \leq l \leq 90.5$, $-0.5 \leq b \leq 0.5$ and is augmented with increased latitude coverage (to $\pm$ 1.5 degrees) toward the Cygnus X region near l 80 and in four strips at $l = 3$, 15, 30, and 31. The area coverage of this section of BGPS is 133 square degrees. In addition, four targeted regions in the outer Galaxy were observed including IC1396 (9 square degrees), the $l = 111$ complex containing NGC7538 (4 square degrees), the W3/4/5 complex (18 square degrees), and Gem OB1 (6 square degrees). The survey has detected approximately 8400 clumps to an rms noise level ranging from 30 to 60 mJy/beam.

The Northern hemisphere BGPS complements the southern hemisphere ATLASGAL survey at the APEX sub-mm telescope in Chile (Schuller et al. 2009) and covers most of the fields soon to be observed by the Hi-GAL consortium using the Herschel Space Observatory.

The data release includes fully reduced FITS map files, noise maps, and a catalog of sources produced by a custom catalog algorithm. BGPS sources are usually extended asymmetric structures, so the catalog reports source positions based on the maximum of emission in each source. The maxima are likely the best targets for follow-up observations of these millimeter continuum sources. Source centroids, sizes, and flux densities are also reported. Papers describing the data acquisition, reduction, and catalog production have been submitted to the ApJ (Aguirre et al. 2009; Rosolowsky et al. 2009) and are available from the IPAC site.

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