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## *Abstracts of recently accepted papers*

### **Dispersion in the lifetime and accretion rate of T Tauri discs**

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We compare evolutionary models for protoplanetary discs that include disc winds with observational determinations of the disc lifetime and accretion rate in Taurus. Using updated estimates for stellar ages in Taurus, together with published classifications, we show that the evolution of the disc fraction with stellar age is similar to that derived for ensembles of stars within young clusters. Around 30 percent of stars lose their discs within 1 Myr, while the remainder have disc lifetimes that are typically in the 1-10 Myr range. We show that the latter range of ages is consistent with theoretical models for disc evolution, provided that there is a dispersion of around 0.5 in the log of the initial disc mass. The same range of initial conditions brackets the observed variation in the accretion rate of Classical T Tauri stars at a given age. We discuss the expected lifetime of discs in close binary systems, and show that our models predict that the disc lifetime is almost constant for separations exceeding 10 au. This implies a low predicted fraction of binaries that pair a Classical T Tauri star with a Weak-lined T Tauri star, and is in better agreement with observations of the disc lifetime in binaries than disc models that do not include disc mass loss in a wind.

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Preprints are available at <http://arxiv.org/abs/astro-ph/0303343>

### **Dynamic cores in hydrostatic disguise**

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We discuss the column density profiles of “cores” in three-dimensional SPH numerical simulations of turbulent molecular clouds. The SPH scheme allows us to perform a high spatial resolution analysis of the density maxima (cores) at scales between  $\sim 0.003$  and 0.3 pc. We analyze simulations in three different physical conditions: large scale driving (LSD), small scale driving (SSD), and random Gaussian initial conditions without driving (GC); each one at two different timesteps: before self-gravity has become important ( $t_0$ ), and when gravity has been operating such that 5% of the total mass in the box has been accreted into cores ( $t_1$ ). For this dataset, we perform Bonnor-Ebert fits to the column density profiles of cores found by a clump-finding algorithm. We find that, for the particular fitting procedure we use, 65% of the cores can be matched to Bonnor-Ebert (BE) profiles, and of these, 47% correspond to *stable*

equilibrium configurations with  $\xi_{\max} < 6.5$ , even though the cores analyzed in the simulations are not in equilibrium, but instead are dynamically evolving. The temperatures obtained with the fitting procedure vary between 5 and 60 K (in spite of the simulations being isothermal, with  $T = 11.3$  K), with the peak of the distribution being at  $T = 11$  K, and most clumps having fitted temperatures between 5 and 30 K. Central densities obtained with the BE fit tend to be smaller than the actual central densities of the cores. We also find that for the LSD and GC cases, there are more BE-like cores at  $t_0$  than at  $t_1$  with  $\xi_{\max} \leq 20$ , while in the case of SSD, there are more such cores at  $t_1$  than at  $t_0$ . We interpret this as a consequence of the stronger turbulence present in the cores of run SSD, which prevents good BE fits in the absence of gravity, and delays collapse in its presence. Finally, in some cases we find substantial superposition effects when we analyze the projection of the density structures, even though the scales over which we project are small ( $\sim 0.18$  pc). As a consequence, different projections of the same core may give very different values of the BE fits. Finally, we briefly discuss recent results claiming that Bok globule B68 is in hydrostatic equilibrium, stressing that they imply that this core is unstable by a wide margin. We conclude that fitting BE profiles to observed cores is not an unambiguous test of hydrostatic equilibrium, and that fit-estimated parameters like mass, central density, density contrast, temperature, or radial profile of the BE sphere may differ significantly from the actual values in the cores.

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<http://arxiv.org/abs/astro-ph/0304008>

## The $\sigma$ Orionis Substellar population: VLT spectroscopy and 2MASS photometry

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VLT/FORS spectroscopy and 2MASS near-infrared photometry, together with previously known data, have been used to establish the membership and the properties of a sample of low-mass candidate members of the  $\sigma$  Orionis cluster with masses spanning from  $1 M_{\odot}$  down to about  $0.013 M_{\odot}$  (i.e., deuterium-burning mass limit). We have observed  $K$ -band infrared excess and remarkably intense  $H\alpha$  emission in various cluster members, which, in addition to the previously detected forbidden emission lines and the presence of Li I in absorption at  $6708 \text{ \AA}$ , have allowed us to tentatively classify  $\sigma$  Orionis members as classical or weak-line T Tauri stars and substellar analogs. Variability of the  $H\alpha$  line has been investigated and detected in some objects. Based on the  $K$ -band infrared excesses and the intensity of  $H\alpha$  emission, we estimate that the minimum disk frequency of the  $\sigma$  Orionis low-mass population is in the range 5–12%.

Accepted by *Astronomy & Astrophysics*

Preprint available at <http://xxx.lanl.gov/abs/astro-ph/0303462>.

## A Search for Close Binaries in the $\rho$ Ophiuchus Star-Forming Region

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We have carried out a new, near-infrared speckle imaging survey of 19 members of the young stellar population in the nearby ( $d=140$  pc),  $\rho$  Ophiuchi cloud core. Results for four binary and one newly discovered triple system are reported. Data for all known multiple systems among the pre-main-sequence population of  $\rho$  Oph are tabulated. We

define a *restricted binary fraction*,  $F_{b,r}$  and a *restricted companion fraction*,  $F_{c,r}$ , as counting only those systems most detectable in the present and previous high-resolution near-infrared imaging surveys, having separations between  $0.1''$  and  $1.1''$  and  $K$ -band magnitude differences,  $\Delta K < 3$ . Analysis of all the available multiplicity data results in updated values of  $F_{b,r} = 24 \pm 11\%$  and  $F_{c,r} = 24 \pm 11\%$  for the Ophiuchus pre-main-sequence population. These values are consistent with the values in the Taurus star-forming region, and  $F_{c,r}$  is in excess by a factor of 2 relative to the Main Sequence at the  $1 \sigma$  level.

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## [CI] 492 GHz mapping observations of the high latitude translucent cloud MCLD 123.5+24.9

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We present the first map of the [CI]  $^3P_1 \rightarrow ^3P_0$  fine-structure transition of neutral carbon made towards a translucent molecular cloud (MCLD 123.5+24.9, located in the Polaris Flare). The [CI] observations were made with the Submillimeter Wave Astronomy Satellite and are supplemented by ground based observations of  $^{12}\text{CO}$  and  $^{13}\text{CO}$  rotational transitions. We find that the [CI] emission is spatially extended following the region bright in  $^{12}\text{CO}$ . The [CI] to CO line ratios observed throughout the MCLD 123.5+24.9 cloud are relatively low, and the [CI] line flux density is only  $\sim 50\%$  of the emission by the three lowest CO rotational transitions. However, the ratios are still within the range observed along selected lines of sight towards other diffuse and translucent molecular clouds. Assuming LTE conditions for the neutral atomic carbon with an excitation temperature of 8 K derived from the  $^{12}\text{CO}$  spectra, we derive a total carbon column density of  $(0.25 - 1) \times 10^{17} \text{ cm}^{-2}$  and a C to CO column density ratio between 0.2 and 1.1. Comparison with a PDR (photo-dominated region) model shows that the model consistently would require uncomfortably high values for the gas volume density in order to reproduce the low [CI] to CO line ratios observed ( $n > 10^5 \text{ cm}^{-3}$ ), unless we assume that the line emitting clumps are embedded in an interclump medium with a density of  $n < 10^3 \text{ cm}^{-3}$ . The low density interclump medium does not significantly contribute to the observed [CI] and CO line emission, but the molecular hydrogen in the gas provides an effective shielding for the CO in the embedded clumps by blocking the FUV photons at the frequencies of CO line transition to the pre-dissociation states. This reduces the photodissociation of CO and thus the abundance of neutral and ionized carbon in the denser clumps.

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[cfa-www.harvard.edu/sfgroup/papers/fbensch-mar03.ps](http://cfa-www.harvard.edu/sfgroup/papers/fbensch-mar03.ps)

## On the Radii of Extrasolar Giant Planets

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We have computed evolutionary models for extrasolar planets which range in mass from  $0.1 M_{\text{JUP}}$  to  $3.0 M_{\text{JUP}}$ , and which range in equilibrium temperature from 113 K to 2000 K. We present four sequences of models, designed to show the structural effects of a solid ( $20 M_{\oplus}$ ) core and of internal heating due to the conversion of kinetic to thermal energy at pressures of tens of bars. The model radii at ages of 4–5 Gyr are intended for future comparisons with radii derived from observations of transiting extrasolar planets. To provide such comparisons, we expect that of order 10 transiting planets with orbital periods less than 200 days can be detected around bright ( $V < 10 - 11$ ) main-sequence stars for which accurate well-sampled radial velocity (RV) measurements can also be readily accumulated. Through these observations, structural properties of the planets will be derivable, particularly for low-mass, high-temperature planets. Implications regarding the transiting companion to OGLE-TR-56 recently announced by Konacki et al. are discussed.

With regard to the transiting planet, HD 209458b, we find, in accordance with other recent calculations, that models without internal heating predict a radius that is  $\sim 0.3R_{\text{JUP}}$  smaller than the observed radius. Two resolutions have been proposed for this discrepancy. Guillot & Showman hypothesize that deposition of kinetic wind energy at pressures of tens of bars is responsible for heating the planet and maintaining its large size. Our models confirm that dissipation of the type proposed by Guillot & Showman can indeed produce a large radius for HD 209458b. Bodenheimer, Lin & Mardling suggest that HD 209458b owes its large size to dissipation of energy arising from ongoing tidal circularization of the planetary orbit. This mechanism requires the presence of an additional planetary companion to continuously force the eccentricity. We show that residual scatter in the current RV data set for HD 209458b is consistent with the presence of an as-of-yet undetected second companion, and that further RV monitoring of HD 209458 is indicated.

Tidal circularization theory also can provide constraints on planetary radii. Extrasolar giant planets with periods of order 7 days should be actively circularizing. We find that the observed eccentricities of  $e \sim 0.14$  for both HD 217107b ( $P = 6.276$  d;  $M \sin i = 1.80 M_{\text{JUP}}$ ), and for HD 68988b ( $P = 7.125$  d,  $M \sin i = 1.29 M_{\text{JUP}}$ ) likely indicate either relatively small planetary radii for these objects ( $R \sim 1.1 R_{\text{JUP}}$ ) or tidal quality factors in the neighborhood of  $Q_{\text{P}} \sim 10^7$ . For these two planets, it will be difficult to differentiate the contribution from tidal and kinetic heating. But the radius of HD 168746b ( $P = 6.403$  d,  $M \sin i = 0.23 M_{\text{JUP}}$ ) is sensitive to whether the planet's interior is heated by tidal dissipation or kinetic heating. The tidal circularization time scale of this planet is shorter than the age of its host star, but we show that within the observational uncertainties, the published RV data can also be fit with a circular orbit for this planet. As more RV planets with periods of order a week are discovered,  $Q_{\text{P}}(T_{\text{eq}}, M_{\text{P}})$  and  $R_{\text{P}}(T_{\text{eq}}, M_{\text{P}})$  will become better determined.

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## Abundant gas-phase H<sub>2</sub>O in absorption toward massive protostars

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We present infrared spectra of gas-phase H<sub>2</sub>O around 6  $\mu\text{m}$  toward 12 deeply embedded massive protostars obtained with the Short Wavelength Spectrometer on board the Infrared Space Observatory (ISO). The  $\nu_2$  ro-vibrational band has been detected toward 7 of the sources and the excitation temperatures indicate an origin in the warm gas at  $T_{\text{ex}} \gtrsim 250$  K. Typical derived gas-phase H<sub>2</sub>O abundances are  $\sim 5 \times 10^{-6}$ – $6 \times 10^{-5}$ , with the abundances increasing with the temperature of the warm gas. The inferred gas/solid ratios show a similar trend with temperature and suggest that grain-mantle evaporation is important. The increasing gas/solid ratio correlates with other indicators of increased temperatures. If the higher temperatures are due to a larger ratio of source luminosity to envelope mass, this makes gas-phase H<sub>2</sub>O a good evolutionary tracer. Comparison with chemical models shows that three different chemical processes, ice evaporation, high- $T$  chemistry, and shocks, can reproduce the high inferred gas-phase H<sub>2</sub>O abundances. In a forthcoming paper each of these processes are investigated in more detail in comparison with data from the Long Wavelength Spectrometer on board ISO and the Submillimeter Wave Astronomy Satellite (SWAS). Comparison with existing SWAS data indicates that a jump in the H<sub>2</sub>O abundance is present and that the observed  $\nu_2$  ro-vibrational band traces primarily the warm inner envelope.

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<http://www.strw.leidenuniv.nl/~boonman/papers/h2osws.pdf>

## Theory of Twisted Trunks

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Using the 2.6 m Nordic Optical Telescope we have observed a large number of elephant trunks in several H II regions. Here, we present a small selection of this material consisting of a few large, well-developed trunks, and some smaller ones. We find that: (i) the well-developed trunks are made up of dark filaments and knots which show evidence of twisted structures, (ii) the trunks are connected with essentially two filamentary legs running in V-shape, and (iii) all trunks have the maximum extinction in their heads. We advance a theory of twisted elephant trunks which is based on the presence of magnetic flux ropes in molecular clouds where hot OB stars are formed. If the rope contains a local condensation it may adopt a V-shape as the HII region around the hot stars expands. If, in addition, the magnetic field in the rope is sufficiently twisted, the rope may form a double helix at the apex of the V. The double helix is identified with the twisted elephant trunks. In order to illustrate the mechanisms behind the double helix we have constructed a mechanical analogy model of the magnetic flux rope in which the rope has been replaced by a bundle of elastic strings loaded by a weight. Experiments with the model clearly show that part of the bundle will transform into a double helix when the twist of the bundle is sufficiently large. We have also worked out a simple theoretical model of a mass-loaded magnetic flux rope. Numerical calculations show that a double helix will indeed form when the twist of the rope exceeds a certain critical limit. Numerical model calculations are applied to both the analogy model experiments and one of the well-developed elephant trunks. On the basis of our model we also suggest a new interpretation of the so called EGGs.

The double helix mechanism is quite general, and should be active also in other suitable environments. One such environment may be the shell of supernova remnants. Another example is the expanding bubble outlined by the North Celestial Pole Loop

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## Adaptive optics imaging survey of the Tucana-Horologium association

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We present the results of an adaptive optics (AO) imaging survey of the common associations of Tucana and Horologium, carried out at the ESO 3.6m telescope with the ADONIS/SHARPII system. Based on our observations of two dozen probable association members, HIP 1910 and HIP 108422 appear to have low-mass stellar companions, while HIP 6856 and GSC 8047-0232 have possible sub-stellar candidate companions. Astrometric measurements, performed in November 2000 and October 2001, indicate that HIP 1910 B likely is bound to its primary, but are inconclusive in the case of the candidate companion to HIP 6856. Additional observations are needed to confirm the HIP 6856 companionship as well as for HIP 108422 and GSC 8047-0232.

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## The mass-velocity and intensity-velocity relations in jet-driven molecular outflows

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We use numerical simulations to examine the mass-velocity and intensity-velocity relations in the CO J=2-1 and H<sub>2</sub> S(1)1-0 lines for jet-driven molecular outflows. Contrary to previous expectations, we find that the mass-velocity

relation for the swept-up gas is a single power-law, with a shallow slope  $\simeq -1.5$  and no break to a steeper slope at high velocities. An analytic bowshock model with no post-shock mixing is shown to reproduce this behaviour very well.

We show that molecular dissociation and the temperature dependence of the line emissivity are both critical in defining the shape of the line profiles at velocities above  $\sim 20 \text{ km s}^{-1}$ . In particular, the simulated CO J=2-1 intensity-velocity relation does show a break in slope, even though the underlying mass distribution does not. These predicted CO profiles are found to compare remarkably well with observations of molecular outflows, both in terms of the slopes at low and high velocities and in terms of the range of break velocities at which the change in slope occurs. Shallower slopes are predicted at high velocity in higher excitation lines, such as H<sub>2</sub> S(1)1-0.

This work indicates that, in jet-driven outflows, the CO J=2-1 intensity profile reflects the slope of the underlying mass-velocity distribution only at velocities  $\leq 20 \text{ km/s}$ , and that higher temperature tracers are required to probe the mass distribution at higher speed.

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Preprints available from <http://www.dcu.ie/~downest/documents/papers/outflows.ps.gz>

## No Fossil Disk in the T Tauri Multiple System V773 Tau

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We present new multi-epoch near-infrared and optical high-angular images of the V 773 Tau pre-main sequence triple system, a weak-line T Tauri (WTTS) system in which the presence of an evolved, “fossil” protoplanetary disk has been inferred on the basis of a significant infrared excess. Our images reveal a fourth object bound to the system, V 773 Tau D. While it is much fainter than all other components at  $2 \mu\text{m}$ , it is the brightest source in the system at  $4.7 \mu\text{m}$ . We also present medium-resolution *K* band adaptive optics spectroscopy of this object, which is featureless with the exception of a weak Br $\gamma$  emission line. Based on this spectrum and on the spectral energy distribution of the system, we show that V 773 Tau D is another member of the small class of “infrared companions” (IRCs) to T Tauri stars (TTS). It is the least luminous, and probably the least massive, component of the system, as opposed to most other IRCs, which suggests that numerous low-luminosity IRCs such as V 773 Tau D may still remain to be discovered. Furthermore, it is the source of the strong IR excess in the system. We therefore reject the interpretation of this excess as the signature of a fossil (or “passive”) disk and further suggest that these systems may be much less frequent than previously thought.

We further show that V 773 Tau C is a variable classical TTS (CTTS) and that its motion provides a well constrained orbital model. We show that V 773 Tau D can be dynamically stable within this quadruple system if its orbit is highly inclined. Finally, V 773 Tau is the first multiple system to display such a variety of evolutionary states (WTTS, CTTS, IRC), which may be the consequence of the strong star-star interactions in this compact quadruple system.

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Preprint available at <http://xxx.lanl.gov/abs/astro-ph/0303648>

## The BP Tau disk: a missing link between Class II and III objects?

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We present new single-dish (30-m) observations and an improved analysis of our earlier interferometric observations (Simon et al. 2000) of BP Tau. Our analysis yields a detailed description of the properties of the circumstellar disk. The disk is small (outer radius 120 AU) and marginally optically thick in the <sup>12</sup>CO J=2→1 line. It is also relatively

hot, about 50 K at 100 AU. The mm continuum emission is consistent with a thermal emission from circumstellar dust with an emissivity index  $\beta \simeq 0.7$ , and a disk mass about  $1.2 \cdot 10^{-3} M_{\odot}$ . The anomalously low  $^{12}\text{CO}$  to dust emission ratio implies that either CO is depleted by a factor of order 150 with respect to  $\text{H}_2$ , or a very low gas to dust ratio, or highly anomalous dust properties. The disk exhibits direct evidence for Keplerian rotation, but because of a combination of insufficient resolution and optically thin CO emission, the mass derived for the star remains inaccurate (between 0.6 and  $1.3 M_{\odot}$  for 140 pc). The unusual properties of the circumstellar disk suggest that BP Tau may be a transient object in the process of clearing its disk.

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## The influence of grains on the propagation and structure of C-type shock waves in interstellar molecular clouds

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Gas-grain interactions can have important consequences for the physics and chemistry of shock waves propagating in molecular clouds. The grains can be both a source and a sink of molecules, and their inertia can modify the dynamics of the propagation of, in particular, C-type shock waves. The degree of charging of the grains, both in the preshock gas and in the shock wave itself, is a significant parameter. The population of interstellar grains extends from large molecules, which we represent by polycyclic aromatic hydrocarbons, to much larger particles, composed of silicates and amorphous carbon material. The influence of the inertia of the grains on the dynamics of the flow is modelled in detail. We find that collisions between charged and neutral grains, driven by ion-neutral drift in C-type shock waves, may lead to the shattering of a large fraction of the amorphous carbon material.

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## The role of ambipolar diffusion in the fragmentation of condensations of the primordial gas

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We consider the evolution and fragmentation of cylindrical filaments of the primordial gas. The filaments are formed following shock compression and heating, occurring subsequent to the gravitational collapse of condensations of the primordial medium. The role of ambipolar diffusion is studied, under circumstances where the magnetic energy density is comparable with the thermal energy density in the filaments, prior to their collapse. It is shown that ambipolar diffusion reduces the masses of the fragments by about an order of magnitude when the fractional ionization of the gas  $n(\text{H}^+)/n(\text{H})$  is of the order of  $10^{-8}$  or less. Under these conditions, ambipolar diffusion is sufficiently rapid for the fragment masses to be similar to those computed neglecting the magnetic field. Attention is drawn to the importance of the  $\text{H}^+ (\text{H}_2, h\nu) \text{H}_3^+$  reaction, whose rate coefficient is very uncertain.

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## The Orion nebula (M42) Herbig-Haro object, HH 201, within the tip of a molecular finger

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The most prominent Herbig-Haro (HH) object, HH 201, in the Orion nebula is investigated using optical spectroscopy along with optical and infrared images. An infrared Subaru H<sub>2</sub>  $v = 1-0$  S(1) image of the region surrounding HH 201's optical line emission has yielded the discovery of a faint H<sub>2</sub> finger associated with HH 201. The H<sub>2</sub> finger is seen to share a common width and orientation with the optical line emission. Therefore, it is unlikely that the association is caused by a chance superposition along the line of sight. The finger is found to precede the optical line emission, which is inconsistent with this H<sub>2</sub> emission being produced within a bowshock. The origin of this finger is discussed in the context of the current understanding of HH objects and the Orion molecular fingers.

Multi-epoch *HST* [S II] 6716 & 6731 Å images are used to measure the proper motions of the various knots present in the filamentary structure of HH 201. Tangential velocities of between 40 km s<sup>-1</sup> and 178 km s<sup>-1</sup> are found. Two new knots with associated proper motions are found in the wake of HH 201 and the general structure of the tangential flow is shown by means of a multi-epoch difference image.

[S II] 6716 & 6731 Å spectra taken with the RGO spectrograph are used to spectroscopically resolve the velocity profile of HH 201 into distinct components with radial velocities of between -267 km s<sup>-1</sup> and -9 km s<sup>-1</sup>. Using the [S II] 6716 & 6731 Å line ratios, the local electron density of gas at the various velocities is found to be between 830 cm<sup>-3</sup> and 12200 cm<sup>-3</sup>. Combining radial and tangential velocities, the angle between the direction of motion and the line of sight is found to be approximately 30°. Assuming that the emission knots and velocity components correspond to condensations in a bowshock, a shock velocity at the head of HH 201 of 295 km s<sup>-1</sup> is established. Using this combination of optical and infrared data, the morphology and kinematics of HH 201 and its immediate environs are elucidated.

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## Evidence for a T Tauri Phase in Young Brown Dwarfs

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As part of a multi-faceted program to investigate the origin and early evolution of sub-stellar objects, we present high-resolution Keck optical spectra of 14 very low mass sources in the IC 348 young cluster and the Taurus star-forming cloud. All of our targets, which span a range of spectral types from M5 to M8, exhibit moderate to very strong H $\alpha$  emission. In half of the IC 348 objects, the H $\alpha$  profiles are broad and asymmetric, indicative of on-going accretion. Of these, IC348-355 (M8) is the lowest mass object to date to show accretion-like H $\alpha$ . Three of our  $\sim$  M6 IC 348 targets with broad H $\alpha$  also harbor broad OI (8446Å) and CaII (8662Å) emission, and one shows broad HeI (6678Å) emission; these features are usually seen in strongly accreting classical T Tauri stars. We find that in very low mass accretors, the H $\alpha$  profile may be somewhat narrower than that in higher mass stars. We propose that low accretion rates combined with small infall velocities at very low masses can conspire to produce this effect. In the non-accretors in our sample, H $\alpha$  emission is commensurate with, or higher than, saturated levels in field M dwarfs of similar spectral type. Our results constitute the most compelling evidence to date that young brown dwarfs undergo a T Tauri-like accretion phase similar to that in stars. This is consistent with a common origin for most low-mass stars, brown dwarfs and isolated planetary mass objects.

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## The G11.11-0.12 Infrared-Dark Cloud: Anomalous Dust and a Non-Magnetic Isothermal Model

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The G11.11-0.12 Infrared-Dark Cloud has a filamentary appearance, both in absorption against the diffuse  $8\mu\text{m}$  Galactic background, and in emission from cold dust at  $850\mu\text{m}$ . Detailed comparison of the dust properties at these two wavelengths reveals that standard models for the diffuse interstellar dust in the Galaxy are not consistent with the observations. The ratio of absorption coefficients within the cloud is  $\kappa_8/\kappa_{850} \leq 1010$ , which is well below that expected for the diffuse ISM where  $\kappa_8/\kappa_{850} \sim 1700$ . This may be due to the formation of ice mantles on the dust and grain coagulation, both of which are expected within dense regions of molecular clouds. The  $850\mu\text{m}$  emission probes the underlying radial structure of the filament. The profile is well represented by a marginally resolved central region and a steeply falling envelope, with  $\Sigma(r) \propto r^{-\alpha}$ , where  $\alpha \geq 3$ , indicating that G11.11-0.12 is the first observed filament with a profile similar to that of a non-magnetic isothermal cylinder.

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## The Physical and Chemical Status of Pre-protostellar Core B68

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We have investigated the physical and chemical status of the pre-protostellar core B68. A previous extinction study suggested that the density profile of B68 is remarkably consistent with a Bonnor-Ebert sphere with  $2.1 M_{\odot}$  at 16 K. We mapped B68 in  $\text{C}_3\text{H}_2$ , CCS, and  $\text{NH}_3$  with the Deep Space Network (DSN) 70m telescope at Goldstone. Our results show that the  $\text{NH}_3$  peak coincides with the dust continuum peak, whereas CCS and  $\text{C}_3\text{H}_2$  are offset from the  $\text{NH}_3$  and dust peaks. The B68 chemical structure is consistent with that seen in other such pre-protostellar cores (L1498, L1544) and is explained by time dependent chemical models that include depletion. We measured the kinetic temperature of B68 with  $\text{NH}_3$  (1,1) and (2,2) spectra obtained with a DSN 34m telescope. We find that the kinetic temperature of B68 is only 11 K which is significantly lower than that previously assumed. We also derive the non-thermal linewidth in B68, and show that B68 is thermally dominated with little contribution from turbulence support ( $< 10\%$ ). We consider a modified Bonnor-Ebert sphere to include effects of turbulence and magnetic fields and use it to constrain the uncertainties in its distance determination. We conclude that the distance to B68 is  $\sim 95\text{pc}$  with a corresponding mass of  $\sim 1.0 M_{\odot}$ . If some magnetic field is present it can be further away (beyond  $\sim 100\text{pc}$ ) and still satisfy the density structure of a Bonnor-Ebert sphere. The sulfur (CS and CCS) and carbon chain ( $\text{C}_3\text{H}_2$ ) molecules are heavily depleted in B68 and do not trace the dense interior region. We see some evidence for depletion of  $\text{NH}_3$  at the core center roughly on a scale similar to that of  $\text{N}_2\text{H}^+$ . Our observations do not preclude any instability such as the onset of collapse, or slow contraction, occurring in the center of the core, which cannot be resolved with our beam size ( $45''$ ).

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## Envelope Emission in Young Stellar Systems: A Sub-Arcsecond Survey of Circumstellar Structure

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We present modeling results for six of the eleven deeply embedded systems from our sub-arcsecond  $\lambda = 2.7\text{ mm}$  continuum interferometric survey. The modeling, performed in the  $u, v$  plane, assumes dust properties, allows for

a power-law density profile, uses a self-consistent, luminosity conserving temperature profile, and has an embedded point source to represent a circumstellar disk. Even though we have the highest spatial resolution to date at these wavelengths, only the highest signal-to-noise systems can adequately constrain the simple self-similar collapse models. Of the six sources modeled, all six were fit with a density power-law index of 2.0; however, in half of the systems, those with the highest signal-to-noise, a density power-law index of 1.5 can be rejected at the 95% confidence level. Further, we modeled the systems using the pure Larson-Penston (LP) and Shu solutions with only age and sound speed as parameters. Overall, the LP solution provides a better fit to the data, both in likelihood and providing the observed luminosity, but the age of the systems required by the fits are surprising low (1000-2000 yrs). We suggest that either there is some overall time scaling of the self-similar solutions that invalidate the age estimates, or more likely we are at the limit of the usefulness of these models. With our observations we have begun to reach the stage where models need to incorporate more of the fundamental physics of the collapse process, probably including magnetic fields and/or turbulence. In addition to constraining collapse solutions, our modeling allows the separation of large-scale emission from compact emission, enabling the probing of the circumstellar disk component embedded within the protostellar envelope. Typically 85% or more of the total emission is from the extended circumstellar envelope component. Using HL Tauri as a standard candle, the range of circumstellar disk masses allowed in our models is 0.0 to 0.12 solar masses; our Class 0 systems do not have disks that are significantly more massive than those in Class I/II systems. This implies that the disk in Class 0 systems must quickly and efficiently process  $\sim 1$  solar mass of material from the envelope onto the protostar.

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## The First Detection of Spatially Resolved Mid-Infrared Scattered Light from a Protoplanetary Disk

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We report spatially resolved  $11.8\ \mu\text{m}$  images, obtained at the W. M. Keck 10 m telescope, of the protoplanetary disk around the pre-main-sequence star HK Tau B. The mid-infrared morphology and astrometry of HK Tau B with respect to HK Tau A indicate that the flux observed in the mid-infrared from HK Tau B has been scattered off the upper surface of its nearly edge-on disk. This is the first example of a protoplanetary disk observed in scattered light at mid-infrared wavelengths. Monte Carlo simulations of this disk show that the extent (FWHM= $0''5$ , or 70 AU) of the scattered light nebula in the mid-infrared is very sensitive to the dust size distribution. The  $11.8\ \mu\text{m}$  measurement can be best modelled by a dust grain population that contains grains on the order of  $1.5\text{-}3\ \mu\text{m}$  in size; grain populations with exclusively sub-micron grain sizes or power law size distributions that extend beyond  $5\ \mu\text{m}$  cannot reproduce the observed morphology. These grains are significantly larger than those expected in the ISM implying that grain growth has occurred; whether this growth is a result of dust evolution within the disk itself or had originally occurred within the dark cloud remains an open question.

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## The protostellar mass limit for 6.7 GHz methanol masers I. A low-mass YSO survey

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We report the results of a search for 6.7 GHz methanol masers toward low-mass young stellar objects (YSOs) and (pre)protostellar condensations with the Australia Telescope Compact Array (ATCA). Our sample consisted of 13 class 0 protostars and 44 class I YSOs as well as 65 (pre)protostellar condensations. A single detection was obtained toward

NGC 2024:FIR4 in the Orion B region. This is the first detection of a 6.7 GHz methanol maser in Orion. The nature of FIR4 has been a subject of debate with some evidence suggesting that it is a very cold high-mass (pre)protostellar condensation and others arguing that it is a low-mass YSO. The discovery of a methanol maser associated with this source is inconsistent with both of these hypotheses and we suggest that FIR4 probably harbours an intermediate- or high-mass YSO. The less massive objects in our sample do not exhibit any methanol maser stronger than 400 mJy ( $4\sigma$ ). Based on the nil detection rate toward the low-mass YSOs we can place an upper limit of  $3 \times 10^6$  K on the brightness temperature of any methanol maser associated with class 0, I or II sources. These results support the hypothesis that no strong methanol masers are associated with low-mass star formation (lta  $3 M_{\odot}$ ).

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## Accretion in Young Stellar/Substellar Objects

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We present a study of accretion in a sample of 45 young, low mass objects in a variety of star forming regions and young associations, about half of which are likely substellar. Based primarily on the presence of broad, asymmetric H $\alpha$  emission, we have identified 13 objects ( $\sim 30\%$  of our sample) which are strong candidates for ongoing accretion. At least 3 of these are substellar. We do not detect significant continuum veiling in most of the accretors with late spectral types (M5-M7). Accretion shock models show that lack of measurable veiling allows us to place an upper limit to the mass accretion rates of  $< 10^{-10} M_{\odot} \text{ yr}^{-1}$ . Using magnetospheric accretion models with appropriate (sub)stellar parameters, we can successfully explain the accretor H $\alpha$  emission line profiles, and derive quantitative estimates of accretion rates in the range  $10^{-12} < \dot{M} < 10^{-9} M_{\odot} \text{ yr}^{-1}$ . There is a clear trend of decreasing accretion rate with stellar mass, with mean accretion rates declining by 3-4 orders of magnitude over  $\sim 1 - 0.05 M_{\odot}$ .

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## Infrared observations of NGC 3603

### III. The enigmatic, highly reddened sources of IRS 9

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In the framework of a multi-wavelengths study of NGC 3603 we have performed near and mid infrared imaging to investigate the nature and the evolutionary status of the highly reddened sources NGC 3603 IRS 9A–C. These sources are located on the OB cluster facing side of the massive molecular cloud core NGC 3603 MM 2 and were apparently only recently revealed from most of their natal environment by strong stellar winds and energetic radiation originating from the nearby high mass cluster stars.

On the basis of the steeply rising spectral energy distributions and the large near and mid infrared excess emission we conclude that IRS 9A–C represent (the brightest members of) a sparse association of high mass protostars, solely embedded in the gravitationally bound material of their circumstellar envelopes but largely blown free from gas + dust of the pristine molecular cloud core.

Fitting blackbody functions to the overall spectral energy distribution at near and mid infrared wavelengths we identify two dust components at temperatures of 250 K and 1150 K for IRS 9A and 250 K and 700-750 K for IRS 9B / 9C. From the mid infrared fluxes we deduce lower limits for the gas + dust masses of the circumstellar envelopes:  $\gtrsim 0.1 M_{\odot}$  for IRS 9A and  $\gtrsim 3 \cdot 10^{-3} M_{\odot}$  for IRS 9B / 9C. Estimates of the total luminosities are on the order of  $10^5 L_{\odot}$  and  $10^3 L_{\odot}$  for IRS 9A and IRS 9B / 9C, respectively.

Finally, our interpretation of IRS 9A–C being protostars is supported by recent ATCA data. The measured 3 cm and

6 cm radio fluxes of IRS 9A can neither be explained by non-thermal emission nor by thermal dust emission. From the spectral index  $\alpha_{\text{radio}} \sim 0.3$  we conclude that the observed radio emission is thermal bremsstrahlung and most likely excited externally by ionizing photons originating from the nearby OB cluster.

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## The lithium depletion boundary and the age of NGC 2547

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We present the results of a photometric and spectroscopic survey of cool M dwarf candidates in the young open cluster NGC 2547. Using the 2dF fiber spectrograph, we have searched for the luminosity at which lithium remains unburned in an attempt to constrain the cluster age. The lack of a population of individual lithium-rich objects towards the faint end of our sample places a very strong lower limit to the cluster age of 35 Myr. However, the detection of lithium in the averaged spectra of our faintest targets suggests that the lithium depletion boundary lies at  $9.5 < M_I < 10.0$  and that the cluster age is  $< 54$  Myr. The age of NGC 2547 judged from fitting isochrones to low-mass pre-main-sequence stars in colour-magnitude diagrams is 20–35 Myr using the same evolutionary models. The sense and size of the discrepancy in age determined by these two techniques is similar to that found in another young cluster, IC 2391, and in the low-mass pre main-sequence binary system, GJ 871.1AB. We suggest that the inclusion of rotation or dynamo-generated magnetic fields in the evolutionary models could reconcile the two age determinations, but only at the expense of increasing the cluster ages beyond that currently indicated by the lithium depletion. Alternatively, some mechanism is required that increases the rate of lithium depletion in young, very low-mass fully convective stars.

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## A <sup>13</sup>CO and C<sup>18</sup>O Survey of the Molecular Gas Around Young Stellar Clusters Within 1 kpc of the Sun

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As the first step of a multi-wavelength investigation into the relationship between young stellar clusters and their environment we present fully-sampled maps in the J=1–0 lines of <sup>13</sup>CO and C<sup>18</sup>O and the J=2–1 line of C<sup>18</sup>O for a selected group of thirty young stellar groups and clusters within 1 kpc of the Sun. This is the first systematic survey of these regions to date. The clusters range in size from several stars to a few hundred stars. Thirty fields ranging in size from 8' × 8' to 30' × 60' were mapped with 47'' resolution simultaneously in the two J=1–0 lines at the Five College Radio Astronomy Observatory. Seventeen sources were mapped over fields ranging in size from 3' × 3' to 13' × 13' in the J=2–1 line with 35'' resolution at the Submillimeter Telescope Observatory. We compare the cloud properties derived from each of the three tracers in order to better understand systematic uncertainties in determining masses and linewidths. Cloud masses are determined independently using the <sup>13</sup>CO and C<sup>18</sup>O transitions; these masses range from 30 to 4000 M<sub>⊙</sub>. Finally, we present a simple morphological classification scheme which may serve as a rough indicator of cloud evolution.

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## Carbon Monoxide Depletion in Orion B Molecular Cloud Cores

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We have observed several cloud cores in the Orion B (L1630) molecular cloud in the 2–1 transitions of C<sup>18</sup>O, C<sup>17</sup>O and <sup>13</sup>C<sup>18</sup>O. We use these data to show that a model where the cores consist of very optically thick C<sup>18</sup>O clumps cannot explain their relative intensities. There is strong evidence that the C<sup>18</sup>O is not very optically thick. The CO emission is compared to previous observations of dust continuum emission to deduce apparent molecular abundances. The abundance values depend somewhat on the temperature but relative to ‘normal abundance’ values, the CO appears to be depleted by about a factor of 10 at the core positions. CO condensation on dust grains provides a natural explanation for the apparent depletion both through gas-phase depletion of CO, and through a possible increase in dust emissivity in the cores. The high brightness of HCO<sup>+</sup> relative to CO is then naturally accounted for by time-dependent interstellar chemistry starting from ‘evolved’ initial conditions. Theoretical work has shown that condensation of H<sub>2</sub>O, which destroys HCO<sup>+</sup>, would allow the HCO<sup>+</sup> abundance to increase while that of CO is falling.

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## Evidence for Grain Growth in the Protostellar Disks of Orion

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We present a Bra $\alpha$  ( $\lambda = 4.05 \mu\text{m}$ ) image of the largest silhouette proplyd in Orion (114-426) using the facility near-IR spectrometer NIRSPEC at the Keck Observatory. This is the longest wavelength observation of a silhouette disk to date. The diameter of the disk at  $4 \mu\text{m}$  is only marginally smaller than that observed in the optical with the *Hubble Space Telescope*. This may be the first signature of chromatic extinction for the translucent outer edges of the disk, suggesting that the near-infrared opacity is dominated by processed grains with typical sizes  $> 1.9 \mu\text{m}$ , but *not*  $\gg 4 \mu\text{m}$ .

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Preprints — <http://www.astro.ucla.edu/~shuping/research/OrionProplyds>

## Numerous Proplyd Candidates in the Harsh Environment of the Carina Nebula

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We report the discovery of dozens of compact objects in the Carina Nebula (NGC 3372) that closely resemble proplyds (photoablating proto-planetary disks and dark silhouette disks) seen previously in the Orion Nebula. This is the first detection of a large number of such objects outside Orion. They imply that low- and intermediate-mass star formation is proceeding actively in Carina, despite threatening conditions imposed by very hot massive stars. The proplyd

candidates that we have detected are larger than those in Orion, but more compact than irregular molecular globules within the H II region. Smaller proplyds may still be lurking in Carina, waiting to be discovered. Orion apparently lacks objects of comparable size, and we consider several explanations. Larger proplyds may come from larger and more massive circumstellar disks surrounding young Herbig Ae/Be stars that should be numerous in Carina. Alternatively, far-UV radiation from the massive star  $\eta$  Carinae may have, in the recent past, enhanced photoablation and expanded proplyd ionization fronts. Some unusual proplyd candidates may also imply that time-dependent effects associated with  $\eta$  Car's current evolutionary state may be critical.

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## Multi-wavelength spectroscopy of the bipolar outflow from Cepheus E

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Cepheus E is the site of an exceptional example of a protostellar outflow with a very young dynamical age and extremely high near infrared luminosity. We combine molecular spectroscopic data from the submillimeter to the near infrared in order to interpret the rotational excitation of CO and the ro-vibrational excitation of H<sub>2</sub>. We conclude that C-type shocks with a paraboloidal bow shock geometry can simultaneously explain all the molecular excitations. Extinction accounts for the deviation of the column densities from local thermodynamic equilibrium. A difference in the extinction between the red and blue-shifted outflow lobes may account for the measured flux difference. The outflow is deeply embedded in a clump of density  $10^5 \text{ cm}^{-3}$ , yet a good fraction of atomic hydrogen, about 40%, is required to explain the excitation and statistical equilibrium. We propose that this atomic component arises, self-consistently, from the dissociated gas at the apex of the leading bow shocks and the relatively long molecule reformation time. At least 20 bow shocks are required in each lobe, although these may be sub-divided into smaller bows and turbulent shocked regions. The total outflow mechanical power and cooling amounts to over  $30 L_{\odot}$ , almost half the source's bolometric luminosity. Nevertheless, only about 6% of the clump mass has been set in outward motion by the outflow, allowing a collapse to continue.

Accepted by Astrophys. J.

Preprints available at <http://www.tls-tautenburg.de/research/research.html>

## Interaction between the Outflow and the Core in IRAM 04191+1522

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We have carried out mapping observations of the molecular core associated with the young Class 0 protostar, IRAM 04191+1522, in the CH<sub>3</sub>OH ( $J_K=2_K-1_K$ ) and C<sup>34</sup>S ( $J=2-1$ ) lines using the 45 m telescope at Nobeyama Radio Observatory. Our observations have revealed that there is a condensation associated with the protostar, elongated in the east-west direction mostly perpendicular to the axis of the associated CO outflow. Its size and mass are estimated to be  $0.07 \text{ pc} \times 0.04 \text{ pc}$  and  $2.3 M_{\odot}$ , respectively, from the CH<sub>3</sub>OH data. In addition to the elongated envelope, two compact ( $\sim 0.03 \text{ pc}$ ) condensations were found in the CH<sub>3</sub>OH line at the southern edge of the elongated envelope, where the blueshifted CO outflow emerging from the protostar is located. In contrast to the elongated envelope, those compact CH<sub>3</sub>OH condensations show much larger line width (up to  $2.0 \text{ km s}^{-1}$ ) with centroid velocities blueshifted by  $\sim 0.8 \text{ km s}^{-1}$ . The compact condensations have momenta ( $\sim 0.06 M_{\odot} \text{ km s}^{-1}$ ) comparable to that of the blueshifted molecular outflow. In addition, they are gravitationally unbound, and most probably will dissipate eventually. These results suggest that the compact condensations are probably formed in the course of interaction between the outflow and the ambient gas surrounding the protostar, and that such interaction may cause dissipation of a part of the ambient gas. No drastic, localized enhancement of the CH<sub>3</sub>OH abundance is, however, observed toward the compact condensations, implying that there seems to be no significant shock heating at the compact condensations in spite of

the interaction with the outflow. This may be because the CO outflow velocity ( $< 10 \text{ km s}^{-1}$ ) is too low to cause effective heating to release  $\text{CH}_3\text{OH}$  on dust grains into gas phase.

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## Large grains in the disk of CQ Tau

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We present 7mm observations of the dusty disk surrounding the 10 Myr old  $1.5 M_{\odot}$  pre-main-sequence star CQ Tauri obtained at the Very Large Array with 0.8 arcsecond resolution and 0.1 mJy rms sensitivity. These observations resolve the 7mm emission in approximately the north-south direction, confirming previous results obtained with lower resolution. We use a two-layer flared disk model to interpret the observed fluxes from 7mm to 1.3mm together with the resolved 7mm structure. We find that the disk radius is constrained to the range 100 to 300 AU, depending on the steepness of the disk surface density distribution. The power law index of the dust opacity coefficient,  $\beta$ , is constrained to be 0.5 to 0.7. Since the models indicate that the disk is optically thin at millimeter wavelengths for radii greater than 8 AU, the contribution of an optically thick region to the emission is less than 10%. This implies that high optical depth or complex disk geometry cannot be the cause of the observed shallow millimeter spectral index. Instead, the new analysis supports the earlier suggestion that dust particles in the disk have grown to sizes as large as a few centimeters. The dust in the CQ Tauri system appears to be evolved much like that in the TW Hydra system, a well-studied pre-main-sequence star of similar age and lower mass. The survival of gas-rich disks with incomplete grain evolution at such old ages deserves further investigations.

Accepted by A&A

<http://www.arcetri.astro.it/~lt/preprints/preprints.html>

## An *IUE* Atlas of Pre–Main-Sequence Stars: III. Coadded Final Archive Spectra from the Long Wavelength Cameras

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We identified 137 T Tauri stars (TTS) and 97 Herbig Ae/Be (HAEBE) stars observed by *IUE* in the wavelength interval 1900–3200 Å. Each low resolution ( $R \sim 6$  Å) spectrum was visually inspected for source contamination and data quality, and then all useable spectra were combined to form a single time averaged spectrum for each star. For sources with multiple observations, we characterized variability and compared with previously published amplitudes at shorter wavelengths. We combined several coadded spectra of diskless TTS to produce a pair of intrinsic stellar spectra unaffected by accretion. We then fitted spectra of TTS with the reddened sum of an intrinsic spectrum and a schematic veiling continuum, measuring emission line fluxes from the residuals. We used extinction and distance estimates from the literature to convert measured Mg II line fluxes into intrinsic line luminosities, noting that the *IUE* detection limit introduces a sample bias such that intrinsic line luminosity is correlated with extinction. This sample bias complicates any physical interpretation of TTS intrinsic luminosities. We measured extinction towards HAEBE stars by fitting our coadded *IUE* spectra with reddened spectra of main-sequence stars and also from V band minus 3000 Å color excess. We measured excess line emission and absorption in spectra of HAEBE stars divided by fitted spectra of main-sequence stars, noting that HAEBE stars with an infrared excess indicating circumstellar material typically also have anomalous UV line strengths. In the latter situation, Mg II is usually shallower than in a main-sequence star of the same spectral class, whereas Fe II lines are equally likely to be deeper or shallower. Our

coadded spectra of TTS, HAEBE stars, and main-sequence templates are available electronically.

Accepted by *Astrophys. J. Supp. Ser.*

<http://sprg.ssl.berkeley.edu/cmj/html/preprints.html>

## 2-D Radiative Transfer in Protostellar Envelopes: I. Effects of Geometry on Class I Sources

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We present 2-D radiation transfer models of Class I Protostars and show the effect of including more realistic geometries on the resulting spectral energy distributions and images. We begin with a rotationally flattened infalling envelope as our comparison model, and add a flared disk and bipolar cavity. The disk affects the spectral energy distribution most strongly at edge-on inclinations, causing a broad dip at about  $10\ \mu\text{m}$  (independent of the silicate feature) due to high extinction and low scattering albedo in this wavelength region. The bipolar cavities allow more direct stellar+disk radiation to emerge into polar directions, and more scattering radiation to emerge into all directions. The wavelength-integrated flux, often interpreted as luminosity, varies with viewing angle, with pole-on viewing angles seeing 2-4 times as much flux as edge-on, depending on geometry. Thus, observational estimates of luminosity should take into account the inclination of a source. The envelopes with cavities are significantly bluer in near-IR and mid-IR color-color plots than those without cavities. Using 1-D models to interpret Class I sources with bipolar cavities would lead to an underestimate of envelope mass and an overestimate of the implied evolutionary state. We compute images at near-, mid-, and far-IR wavelengths. We find that the mid-IR colors and images are sensitive to scattering albedo, and that the flared disk shadows the midplane on large size scales at all wavelengths plotted. Finally, our models produce polarization spectra which can be used to diagnose dust properties, such as albedo variations due to grain growth. Our results of polarization across the  $3.1\ \mu\text{m}$  ice feature agree well with observations for ice mantles covering 5% of the radius of the grains.

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preprint available at <http://gemelli.colorado.edu/~bwhitney/preprints.html>

## Trapped Protostellar Winds and their Breakout

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Observations show that high-velocity jets stem from deeply embedded young stars, which may still be experiencing infall from their parent cloud cores. Yet theory predicts that, early in this buildup, any outgoing wind is trapped by incoming material of low angular momentum. As collapse continues and brings in more rapidly rotating gas, the wind can eventually break out. Here we model this transition by following the motion of the shocked shell created by impact of the wind and a rotating, collapsing envelope. We first demonstrate, both analytically and numerically, that our previous, quasi-static solutions are dynamically unstable. Our present, fully time-dependent calculations include cases both where the wind is driven back by infall to the stellar surface, and where it erupts as a true outflow. For the latter, we find that the time of breakout is  $5 \times 10^4\ \text{yr}$  for wind speeds of  $200\ \text{km s}^{-1}$ . The reason for the delay is that the shocked material, including the swept-up infall, must be able to climb out of the star's gravitational potential well.

We explore the critical wind speed necessary for breakout as a function of the mass transport rates in the wind and infall, as well as the cloud rotation rate  $\Omega_0$  and time since the start of infall. Breakout does occur for realistic

parameter choices. The actual breakout times would change if we relaxed the assumption of perfect mixing between the wind and infall material. Our expanding shells do not exhibit the collimation of observed jets, but continue to expand laterally. To halt this expansion, the density in the envelope must fall off less steeply than in our model.

Accepted by ApJ

Preprint available at <http://www.astrosmo.unam.mx/f.wilkin/WSII.ps>

## High resolution imaging of CO outflows in OMC-2 and OMC-3

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A large scale, high resolution map of CO(1–0) emission toward the OMC-2 and OMC-3 star forming regions is presented. The map is a mosaic of 46 fields using the Berkeley-Illinois-Maryland Array (BIMA) and covers  $\sim 10' \times 15'$  at  $\sim 10''$  resolution. These data are combined with singledish FCRAO observations and analyzed to identify and determine the properties of nine protostellar outflows. The BIMA data alone almost completely resolve out the cloud emission at central velocities and only recover 1/20 of the flux in the high velocity gas showing that outflows are generally broadly dispersed over  $\sim 1'$  angular scales. All nine identified outflows emanate from known Class 0 or borderline Class 0/I sources, are associated with knots of shocked H<sub>2</sub> emission, and have short dynamical times. It is suggested that only the youngest, most spatially compact, and energetic outflows have been found and that more distributed high velocity gas undetected by BIMA is due to older outflows continuing through the Class I phase of protostellar evolution. The mechanical energy injection rate into the cloud is estimated to be  $\sim 1.5 L_{\odot}$  which is comparable to the turbulent energy dissipation rate. Outflows appear capable, therefore, of sustaining cloud turbulence but a high star formation rate is required implying a short cloud lifetime  $\leq 5$  Myr.

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## Magnetic field evolution in Bok globules

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Using the Submillimeter Common-User Bolometer Array (SCUBA) at the James Clerk Maxwell Telescope (JCMT), we obtained submillimeter polarization maps of the Bok globules B 335, CB 230, and CB 244 at 850  $\mu\text{m}$ . We find strongly aligned polarization vectors in the case of B 335 and CB 230, indicating a strong coupling of the magnetic field to the dust grains. Based on the distribution of the orientation and strength of the linear polarization we derive the magnetic field strengths in the envelopes of the globules: 134  $\mu\text{G}$  (B 335), 218  $\mu\text{G}$  (CB 230), and 257  $\mu\text{G}$  (CB 244). In agreement with previous submillimeter polarization measurements of Bok globules we find polarization degrees of several percent decreasing towards the centers of the cores. Furthermore, we compare the magnetic field topology with the spatial structure of the globules, in particular with the orientation of the outflows and the orientation of the nonspherical globule cores. In case of the globules B 335 and CB 230, the outflows are oriented almost perpendicular to the symmetry axis of the globule cores. The magnetic field, however, is aligned with the symmetry axis of the prolate cores in the case of the Bok globules B 335 and CB 230, while it is slightly aligned with the outflow axis in the case of the Bok globules CB 26 and CB 54. We discuss the possibility that the different orientations of the magnetic field relative to the outflow directions reflect different evolutionary stages of the single globules.

Accepted by ApJ

Preprint available at:

<http://spider.ipac.caltech.edu/staff/swolf/homepage/public/preprints/mfe.ps.gz>

## *Abstracts of recently accepted major reviews*

### **Embedded Clusters in Molecular Clouds**

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Stellar clusters are born embedded within giant molecular clouds (GMCs) and during their formation and early evolution are often only visible at infrared wavelengths, being heavily obscured by dust. Over the past 15 years advances in infrared detection capabilities have enabled the first systematic studies of embedded clusters in galactic molecular clouds. In this article we review the current state of empirical knowledge concerning these extremely young protocluster systems. From a survey of the literature we compile the first extensive catalog of galactic embedded cluster properties. We use the catalog to construct the mass function and estimate the birthrate for embedded clusters within  $\sim 2$  kpc of the Sun. We find that the embedded cluster birthrate exceeds that of visible open clusters by an order of magnitude or more indicating a high infant mortality rate for protocluster systems. Less than 4-7% of embedded clusters survive emergence from molecular clouds to become bound clusters of Pleiades age. The vast majority (90%) of stars that form in embedded clusters form in rich clusters of 100 or more members with masses in excess of 50  $M_{\text{sun}}$ . Moreover, observations of nearby cloud complexes indicate that embedded clusters account for a significant (70-90%) fraction of all stars formed in GMCs. We review the role of embedded clusters in investigating the nature of the stellar initial mass function (IMF) that, in one nearby example, has been measured over the entire range of stellar and substellar mass, from OB stars to substellar objects near the deuterium burning limit. We also review the role embedded clusters play in the investigation of circumstellar disk evolution and the important constraints they provide for understanding the origin of planetary systems. Finally, we discuss current ideas concerning the origin and dynamical evolution of embedded clusters and the implications for the formation of bound open clusters.

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[http://cfa-www.harvard.edu/~clada/pubs.html/araa\\_cluster.html](http://cfa-www.harvard.edu/~clada/pubs.html/araa_cluster.html)

### **Probing the close environment of young stellar objects with interferometry**

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The study of Young Stellar Objects (YSOs) is one of the most exciting topics that can be undertaken by long baseline optical interferometry. The magnitudes of these objects are at the edge of capabilities of current optical interferometers, limiting the studies to a few dozen, but are well within the capability of coming large aperture interferometers like the VLT Interferometer, the Keck Interferometer, the Large Binocular Telescope or 'OHANA. The milli-arcsecond spatial resolution reached by interferometry probes the very close environment of young stars, down to a tenth of an astronomical unit. In this paper, I review the different aspects of star formation that can be tackled by interferometry: circumstellar disks, multiplicity, jets. I present recent observations performed with operational infrared interferometers, IOTA, PTI and ISI, and I show why in the next future one will extend these studies with large aperture interferometers.

Accepted by Astrophysics & Space Science

Preprint available at <http://arXiv.org/abs/astro-ph/0303260>

## Short Announcements

The Two Micron All Sky Survey (2MASS) is pleased to announce that the All-Sky Data Release Point Source Catalog (PSC) and Extended Source Catalog (XSC) are now available. The All-Sky PSC contains accurate positions and J, H and Ks photometry for over 470 million sources, most of which are stars in the Milky Way. The All-Sky XSC contains positions, three-band photometry and basic shape information for over 1.6 million resolved sources, most of which are galaxies. The 2MASS "Quicklook" Atlas Images, have been available online since October of last year.

An introduction to the Release data products and supporting documentation is available at

<http://www.ipac.caltech.edu/2mass/releases/allsky/>,

or you may access the Catalogs and Images directly from the NASA/Infrared Science Archive at

<http://irsa.ipac.caltech.edu/>.

The Catalogs will soon be available via bulk ftp download and on a limited-distribution DVD-ROM in the near future.

Users are strongly encouraged to review the Explanatory Supplement to the 2MASS All-Sky Data Release at

<http://www.ipac.caltech.edu/2mass/releases/allsky/doc/explsup.html>

for general information about the Survey, the formats, characteristics and cautionary notes about the Catalogs.

User support is available via the 2MASS Help Desk at [2mass@ipac.caltech.edu](mailto:2mass@ipac.caltech.edu).

The Two Micron All Sky Survey is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology. Funding for the survey has been provided by the National Aeronautics and Space Administration and the National Science Foundation.

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, not reviews nor conference notes), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star formation and interstellar medium community), *New Books* (giving details of books relevant for the same community), *New Jobs* (advertising jobs specifically aimed towards persons within our specialty), and *Short Announcements* (where you can inform or request information from the community).

**Latex macros for submitting abstracts and dissertation abstracts are appended to each issue of the newsletter.**

The Star Formation Newsletter is available on the World Wide Web at <http://www.ifa.hawaii.edu/~reipurth> or at <http://www.eso.org/gen-fac/pubs/starform/>.

### Moving ... ??

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

## *Meetings*

### **Early Stages of Star Formation**

Minisymposium held within the framework of JENAM-2003 Symposium,  
Budapest, Hungary, 26-27 August 2003

#### Scientific rationale

In the last decade considerable progress has been made on fundamental issues linked to the star formation process, to the physics of young stellar objects and their circumstellar environment. There remain, however, important open problems related to the understanding of physical processes which lead to the onset of star formation and shape the properties of nascent stellar aggregates.

Why and how do molecular clouds start forming stars? What is the role of turbulence, magnetism and gravity during the star formation process? How do brown dwarfs form? How has the physics of star formation evolved over cosmological time scales due to the varying environment? Theoretical and observational studies of the earliest stages of star formation, as well as numerical modelling of cloud evolution in the last years led to radically new views on these issues.

This mini-symposium will address problems related to the early phases of star formation - starting with the fragmentation and collapse of molecular cloud cores to the time when the forming protostars become visible in the optical - the T Tauri phase. We will discuss observations and theory related to this timespan, in which stars gain most of their final mass. The symposium should include the formation processes of single and multiple stars, as well as accretion and outflow phenomena that are connected to them. Properties of the star formation process in the early universe and their evolution to the present state will also be touched upon.

Main topics of the five sessions of the minisymposium:

- (1) initial conditions, fragmentation
- (2) collapse, accretion, outflows
- (3) clustered and isolated star formation, IMF
- (4) formation of brown dwarfs
- (5) star formation in the early universe

Scientific Organizing Committee:

P. Abraham, Hungary  
J. Alves, ESO  
M. Bate, UK  
J. Eisloffel, Germany (convenor)  
M. Kun, Hungary (convenor)  
H. Zinnecker, Germany

Invited speakers (to be confirmed):

Joao Alves  
Philippe Andre  
Zoltan Haiman  
Ralf Klessen  
Hans Zinnecker

Proceedings of the minisymposium:

Invited and contributed talks, as well as poster presentations will be published by *Baltic Astronomy*.

For more details and registration, see <http://www.konkoly.hu/jenam03/>

## FIRST ANNOUNCEMENT

# The Formation and Evolution of Massive Young Star Clusters

A workshop to be held in Cancun, Mexico from 17-21 November 2003

The workshop on "The Formation and Evolution of Massive Young Clusters" from November 17-21 2003, will be held at the Westin Hotel, Cancun, Mexico. A brief description of the aims of the meeting are given below. More details and a pre-registration [form.html](#) form can be found at [www.star.ucl.ac.uk/clusters](http://www.star.ucl.ac.uk/clusters) <http://www.star.ucl.ac.uk/clusters>. This workshop will be a follow-up to the IAU symposium held in Pucon on "Extragalactic Star Clusters" and the ESO workshop on "Extragalactic Globular Cluster Systems". It will focus on massive ( $> 10^4$  solar masses) young ( $< 1$  Gyr) clusters in galactic and extra-galactic environments.

### Rationale

Over the last decade, the importance of young massive star clusters as signposts to major star formation events has been recognised. They have been discovered near the Galactic Centre, in nearby starburst galaxies, merging galaxies, ultra-luminous infra-red galaxies, and undoubtedly played an important role in early bursts of star formation. Starburst-driven superwinds have been revealed as important sources of regulating star formation and ejecting enriched material into the intergalactic medium. Our understanding of the formation, evolution and eventual fate of massive young star clusters is developing rapidly but there are still many unanswered questions. Observations with, for example, HST, ISO and large ground-based telescopes have allowed us to investigate their formation in giant molecular clouds, to analyse their stellar content, and assess their chances of survival. There has also been much progress in theoretical modelling using computer simulations of cluster formation and N-body codes to trace their dynamical evolution.

### Topics and Deadlines

Properties of Massive Young Clusters; Giant Molecular Clouds; Formation of Clusters; The Structure of Very Young Clusters; Dynamics and Survival; Consequences. We intend that the meeting will be very much a workshop with a strong emphasis on current topics and controversies. There will be sufficient time for lively discussions and the number of participants will be limited to around 80. The proceedings will be published as part of the PASP conference series. The deadlines for pre-registration and final registration are 1st May and 1st July. We will send out a second announcement with details of invited speakers during June.

### Scientific Organising Committee

Henny Lamers (Utrecht, co-chair), Linda Smith (UCL, London, co-chair), Andi Burkert (MPIA, Heidelberg), Cathie Clarke (IOA, Cambridge), Bruce Elmegreen (IBM), Jay Gallagher (Wisconsin), Lynne Hillenbrand (Caltech), Luis Ho (Carnegie), Rob Kennicutt (Arizona), Ariane Lancon (Strasbourg), Philip Myers (CFA, Harvard), Antonella Nota (STScI), Simon Portegies Zwart (Amsterdam), Nick Scoville (Caltech), Brad Whitmore (STScI).

### Local Organising Committee:

Philippe Eenens (Guanajuato, chair), Antonella Nota (STScI)

**<http://www.star.ucl.ac.uk/clusters>**

**Email: [clusters@star.ucl.ac.uk](mailto:clusters@star.ucl.ac.uk)**