

# THE STAR FORMATION NEWSLETTER

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## *Abstracts of recently accepted papers*

### **Luminosity Functions of Young Clusters: Modeling the Substellar Mass Regime**

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We predict near-infrared luminosity functions of young (5 Myr to 1 Gyr) star clusters by combining evolutionary models of very low-mass ( $1 M_J$  to  $0.15 M_\odot$ ) dwarfs with empirical bolometric corrections. We identify several characteristic features in our results. These can be attributed to three causes: (1) deuterium burning in the most massive substellar objects; (2) methane absorption in bodies with  $T_{eff}$  less than 1300 K, the temperature of the L/T transition; and (3) the formation of dust clouds and the rainout of dust at roughly the same effective temperature as methane formation. Accurate reconstruction of the substellar mass function from luminosity function observations requires that these phenomena are taken into account. At present, few observational studies extend to sufficient sensitivities to allow detection of these effects. However, the luminosity function of the young open cluster IC 2391 shows a clear peak at  $M_J \sim 14$  which we attribute to the result of deuterium burning in substellar objects. The location of this feature is a strong function of age, and we estimate an age of 35 Myr for IC 2391. This is significantly younger than the 53 Myr derived from the location of the lithium depletion boundary but agrees with the main sequence turnoff age. We consider the implications of this result and our multi-band luminosity functions for future observational studies. All predicted luminosity function features are, or will be, accessible to observations using new wide-field IR imagers and the Space Infrared Telescope Facility.

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### **Kinetic Temperatures in the Orion Bar**

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We report the detection of the  $(J, K)=(1,1)$ ,  $(2,2)$  and  $(4,4)$  inversion lines of ammonia towards the Photo Dissociation Region (PDR) of the Orion Bar. The  $\text{NH}_3$  emission is found in the same location as emission from HCN. Temperatures determined from line intensity ratios indicate a warm gas with  $T_k$  of  $\sim 150\text{K}$ . This value is inconsistent with temperatures predicted from models of the gas phase chemistry of dense PDRs. We propose that the emission arises from ammonia released into the gas phase from the evaporation of dense clumps. From measurements of the  $J = 2 - 1$  line of  $\text{C}^{18}\text{O}$ , we obtain beam-averaged column densities for those positions where the  $(1,1)$ ,  $(2,2)$  and  $(4,4)$  inversion lines were measured. The ammonia to  $\text{C}^{18}\text{O}$  abundance ratio is  $1.4 \pm 0.5 \cdot 10^{-2}$ .

Accepted by Astronomy & Astrophysics

## Eclipses by circumstellar material in the T Tauri star AA Tau. II. Evidence for non-stationary magnetospheric accretion

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We report the results of a synoptic study of the photometric and spectroscopic variability of the classical T Tauri star AA Tau on timescales ranging from a few hours to several weeks. The AA Tau light curve had been previously shown to vary with a 8.2d period, exhibiting a roughly constant brightness level, interrupted by quasi-cyclic fading episodes, which we interpreted as recurrent eclipses of the central star by the warped inner edge of its accretion disk (Bouvier et al. 1999). Our observations show the system is dynamic and presents non-stationary variability both in the photometry and spectroscopy.

The star exhibits strong emission lines that show substantial variety and variability in their profile shapes and fluxes. Emission lines such as H $\alpha$  and H $\beta$  show both infall and outflow signatures and are well reproduced by magnetospheric accretion models with moderate mass accretion rates ( $10^{-8} - 10^{-9} M_{\odot} \text{yr}^{-1}$ ) and high inclinations ( $i \geq 60^{\circ}$ ). The veiling shows variations that indicate the presence of 2 rotationally modulated hot spots corresponding to the two magnetosphere poles. It correlates well with the HeI line flux, with B-V and the V excess flux. We have indications of a time delay between the main emission lines (H $\alpha$ , H $\beta$  and HeI) and veiling, the lines formed farther away preceding the veiling changes. The time delay we measure is consistent with accreted material propagating downwards the accretion columns at free fall velocity from a distance of about  $8R_{\star}$ . In addition, we report periodic radial velocity variations of the photospheric spectrum which might point to the existence of a  $0.02 M_{\odot}$  object orbiting the star at a distance of 0.08 AU.

During a few days, the eclipses disappeared, the variability of the system was strongly reduced and the line fluxes and veiling severely depressed. We argue that this episode of quiescence corresponds to the temporary disruption of the magnetic configuration at the disk inner edge. The smooth radial velocity variations of inflow and outflow diagnostics in the H $\alpha$  profile yield further evidence for large scale variations of the magnetic configuration on a timescale of a month. These results may provide *the first clear evidence for large scale instabilities developing in T Tauri magnetospheres as the magnetic field lines are twisted by differential rotation between the star and the inner disk*. The interaction between the inner accretion disk and the stellar magnetosphere thus appears to be a highly dynamical and time dependent process.

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## Long-term study of water masers associated with Young Stellar Objects. II: Analysis

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We present the analysis of the properties of water maser emission in 14 star forming regions (SFRs), which have been monitored for up to 13 years with a sampling rate of about once every 2-3 months. The 14 regions were chosen to span a range in luminosity  $L_{\text{fir}}$  of the associated Young Stellar Object (YSO) between  $20 L_{\odot}$  and  $1.8 \times 10^6 L_{\odot}$ . The general scope of the analysis is to investigate the dependence of the overall spectral morphology of the maser emission and its variability on the luminosity of the YSO. We find that higher-luminosity sources tend to be associated with stronger and more stable masers. Higher-luminosity YSOs can excite more emission components over a larger range in velocity, yet the emission that dominates the spectra is at a velocity very near that of the molecular cloud in which the objects are embedded. For  $L_{\text{fir}} \gtrsim 3 \times 10^4 L_{\odot}$  the maser emission becomes increasingly structured and more extended in velocity with increasing  $L_{\text{fir}}$ . Below this limit the maser emission shows the same variety of morphologies, but without a clear dependence on  $L_{\text{fir}}$  and with a smaller velocity extent. Also, for sources with  $L_{\text{fir}}$  above this limit, the water maser is always present above the  $5\sigma$ -level; below it, the typical  $5\sigma$  detection rate is 75-80%. Although the present sample contains few objects with low YSO luminosity, we can conclude that there must be a lower limit to  $L_{\text{fir}}$  ( $\lesssim 430 L_{\odot}$ ), below which the associated maser is below the detection level most of the time. These results can be understood in terms of scaled versions of similar SFRs with different YSO luminosities, each with many potential sites of maser amplification, which can be excited provided there is sufficient energy to pump them, i.e. the basic pumping process is identical regardless of the YSO luminosity. In SFRs with lower input energies, the conditions of maser amplification are much closer to the threshold conditions, and consequently more unstable.

We find indications that the properties of the maser emission may be determined also by the geometry of the SFR, specifically by the beaming and collimation properties of the outflow driven by the YSO.

For individual emission components the presence of velocity gradients seems to be quite common; we find both acceleration and deceleration, with values between  $0.02$  and  $1.8 \text{ km s}^{-1} \text{ yr}^{-1}$ .

From the 14 ‘bursts’ that we looked at in some detail we derive durations of between 60 and 900 days and flux density increases of between 40% and  $\gtrsim 1840\%$  (with an absolute maximum of  $\sim 820 \text{ Jy}$  over 63 days). The ranges found in burst- intensity and -duration are biased by our minimum sampling interval, while the lifetime of the burst is furthermore affected by the fact that bursts of very long duration may not be recognized as such.

In addition to the flux density variations in individual emission components, the  $\text{H}_2\text{O}$  maser output as a whole is found to exhibit a periodic long-term variation in several sources. This may be a consequence of periodic variations in the wind/jets from the exciting YSO.

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Preprints available at [astro-ph/0306249](http://astro-ph/0306249) (some Figs. at lower resolution) or at [http://www.arcetri.astro.it/starform/preprints/brand\\_2.ps.gz](http://www.arcetri.astro.it/starform/preprints/brand_2.ps.gz) (all Figs. original resolution)

## Keck Adaptive Optics Imaging of Nearby Young Stars: Detection of Close Multiple Systems

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Using adaptive optics on the Keck II 10-meter telescope on Mauna Kea, we have surveyed 24 of the nearest young stars known in search of close companions. Our sample includes members of the MBM 12 and TW Hydrae young associations and the classical T Tauri binary UY Aurigae in the Taurus star-forming region. We present relative photometry and accurate astrometry for 10 close multiple systems. The multiplicity frequency in the TW Hydrae and MBM 12 groups are high in comparison to other young regions, though the significance of this result is low because of the small number statistics. We resolve S 18 into a triple system including a tight 63 mas (projected separation of 17 AU at a distance of 275 pc) binary for the first time, with a hierarchical configuration reminiscent of VW Chamaeleontis and T Tauri.

Another tight binary in our sample – TWA 5 Aab (54 mas or 3 AU at 55 pc) – offers the prospect of dynamical mass measurement using astrometric observations within a few years, and thus could be important for testing pre-main sequence evolutionary models. Our observations confirm with  $9\sigma$  confidence that the brown dwarf TWA 5 B is bound to TWA 5 A. We find that the flux ratio of UY Aur has changed dramatically, by more than a magnitude in the  $H$ -band, possibly as a result of variable extinction. With a smaller flux ratio, the system may once again become detectable as an optical binary, as it was at the time of its discovery in 1944. Taken together, our results demonstrate that adaptive optics on large telescopes is a powerful tool for detecting tight companions, and thus exploring the frequency and configurations of close multiple systems. Accepted by The Astronomical Journal

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## Branch, Spur, and Feather Formation in Spiral Galaxies

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We use hydrodynamical simulations to investigate the response of geometrically thin, self-gravitating, singular isothermal disks of gas to imposed rigidly rotating spiral potentials. By minimizing reflection-induced feedback from boundaries, and by restricting our attention to models where the swing parameter  $X \sim 10$ , we minimize the swing amplification of global normal modes even in models where Toomre's  $Q_g \sim 1 - 2$  in the gas disk. We perform two classes of simulations: short-term ones over a few galactic revolutions where the background spiral forcing is large, and long-term ones over many galactic revolutions where the spiral forcing is considerably smaller. In both classes of simulations, the initial response of the gas disk is smooth and mimics the driving spiral field. At late times, many of the models evince substructure akin to the so-called branches, spurs, and feathers observed in real spiral galaxies. We comment on the parts played respectively by ultraharmonic resonances, reflection off internal features produced by nonlinear dredging, and local, transient, gravitational instabilities within spiral arms in the generation of such features. Our simulations reinforce the idea that spiral structure in the gaseous component becomes increasingly flocculent and disordered with the passage of time, even when the background population of old disk stars is a grand-design spiral. We speculate that truly chaotic behavior arises when many overlapping ultraharmonic resonances develop in reaction to an imposed spiral forcing that has itself a nonlinear, yet smooth, wave profile.

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[xxx.lanl.gov/abs/astro-ph/0306472](http://xxx.lanl.gov/abs/astro-ph/0306472)

## The young cluster in the CB34 globule – II. The clumps and the outflows

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The molecular environment of the young cluster of Class 0 YSOs located in the globule CB34 has been investigated through a multiline millimetre survey. The CO, <sup>13</sup>CO, C<sup>18</sup>O, and CS emissions show that the present star forming process is concentrated into three molecular clumps with size of  $\sim 0.25$  pc which are embedded in a cool more extended gas. The spatial distribution of the high-velocity emission reveals the occurrence of multiple outflows which are associated with the brightest YSOs.

The interaction of the outflows with the molecular clumps has been studied by using the abundances of products of shocked chemistry such as SiO and SO. The abundances of these molecules at the high velocities of the outflows can be used to further specify, with respect to the continuum results, the characteristics of the Class 0 YSOs. In particular, one of the YSOs which does not show the presence of SiO and SO at high velocities is thought to be in a more evolved phase where most of the molecules produced at high velocities in the shocked regions have been already destroyed.

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## Observations of DG Tauri with the Keck Interferometer

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We present the first science results from the Keck Interferometer, a direct-detection infrared interferometer utilizing the two 10-meter Keck telescopes. The instrument and system components are briefly described. We then present observations of the T Tauri object DG Tau, which is resolved by the interferometer. The resolved component has a radius of 0.12 to 0.24 AU, depending on the assumed stellar and extended component fluxes and the model geometry used. Possible origins and implications of the resolved emission are discussed.

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Preprints available at [http://planetquest.jpl.nasa.gov/Keck/DGTau\\_preprint.pdf](http://planetquest.jpl.nasa.gov/Keck/DGTau_preprint.pdf)

## Massive stars and the energy balance of the ISM.

### I. The impact of an isolated 60 $M_{\odot}$ star

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We present results of numerical simulations carried out with a 2D radiation hydrodynamics code in order to study the impact of massive stars on their surrounding interstellar medium. This first paper deals with the evolution of the circumstellar gas around an isolated 60  $M_{\odot}$  star. The interaction of the photoionized H II region with the stellar wind bubble forms a variety of interesting structures like shells, clouds, fingers, and spokes. These results demonstrate that complex structures found in H II regions are not necessarily relics from the time before the gas became ionized but may result from dynamical processes during the course of the H II region evolution. We have also analyzed the transfer and deposit of the stellar wind and radiation energy into the circumstellar medium until the star explodes as a supernova. Although the total mechanical wind energy supplied by the star is negligible compared to the accumulated energy of the Lyman continuum photons, the kinetic energy imparted to the circumstellar gas over the star's lifetime is 4 times higher than for a comparable windless simulation. Furthermore, the thermal energy of warm photoionized gas is lower by some 55%. Our results document the necessity to consider both ionizing radiation and stellar winds for an appropriate description of the interaction of OB stars with their circumstellar environment.

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## Disk Properties and Density Structure of the Star-Forming Dense Core B335

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We present subarcsecond resolution dust continuum observations of the protostellar collapse candidate B335 made with the IRAM Plateau de Bure Interferometer at wavelengths of 1.2 and 3.0 mm. These observations probe to  $< 100$  AU size scales and reveal a compact source component that we identify with a circumstellar disk. We analyze these data in concert with previous lower resolution interferometer observations and find a best fit density structure for B335 that consists of a power law envelope with index  $p = 1.55 \pm 0.04$  ( $r \leq 5000$  AU) together with a disk ( $r < 100$  AU) of flux  $F_{1.2\text{mm}} = 21 \pm 2$  mJy. We estimate a systematic uncertainty in the power law index  $\delta p \leq 0.15$ , where the largest error comes from the assumed form of the dust temperature falloff with radius. This determination of the inner density structure of B335 has a precision unique amongst protostellar cores, and it is consistent with the  $r^{-1.5}$  profile of gravitational free-fall, in accord with basic expectations for the formation of a star. The flux (and implied mass) of the compact component in B335 is typical of the disks around T Tauri stars.

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## High-Resolution Spectroscopy of FUors

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High-resolution spectroscopy was obtained of the FUors FU Ori and V1057 Cyg between 1995 and 2002 with the SOFIN spectrograph at NOT and with HIRES at Keck I. During these years FU Ori remained about 1 mag. (in B) below its 1938–39 maximum brightness, but V1057 Cyg (B  $\approx 10.5$  at peak in 1970–71) faded from about 13.5 to 14.9 and then recovered slightly. Their photospheric spectra resemble that of a rotationally broadened, slightly veiled supergiant of about type G0 Ib, with  $v_{eq} \sin i = 70$  km s<sup>-1</sup> for FU Ori, and 55 km s<sup>-1</sup> for V1057 Cyg. As V1057 Cyg faded, P Cyg structure in H $\alpha$  and the IR Ca II lines strengthened, and a complex shortward-displaced shell spectrum of low-excitation lines of the neutral metals (including Li I and Rb I) increased in strength, disappeared in 1999, and reappeared in 2001. Several SOFIN runs extended over a number of successive nights so that a search for rapid and cyclic changes in the spectra was possible. These spectra show rapid night-to-night changes in the wind structure of FU Ori at H $\alpha$ , including clear evidence of sporadic infall. The equivalent width of the P Cyg absorption varied cyclically with a period of 14.8 days, with phase stability maintained over 3 seasons. This is believed to be the rotation period of FU Ori. The internal structure of its photospheric lines also varies cyclically, but with a period of 3.54 days. A similar variation may be present in V1057 Cyg, but the data are much noisier and that result uncertain. As V1057 Cyg has faded and the continuum level fallen, the emission lines of a pre-existing low-excitation chromosphere have emerged. Therefore we believe that the ‘line doubling’ in V1057 Cyg is produced by these central emission cores in the absorption lines, not by orbital motion in an inclined Keplerian disk. No dependence of  $v_{eq} \sin i$  on wavelength or excitation potential was detected in either FU Ori or V1057 Cyg, again contrary to expectation for a self-luminous accretion disk. It was found also that certain critical lines in the near infrared are not accounted for by synthetic disk spectra. It is concluded that a rapidly rotating star near the edge of stability, as proposed by Larson (1980), can better account for these observations. The possibility is also considered that FUor eruptions are not a property of ordinary T Tauri stars, but may be confined to a special sub-species of rapidly rotating pre-main sequence stars having powerful quasi-permanent winds.

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# Molecular Counterparts of Ultracompact HII Regions with Extended Envelopes

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We have carried out  $^{13}\text{CO}$  J=1–0, CS, and  $\text{C}^{34}\text{S}$  J=2–1 and J=3–2 line observations of molecular clouds associated with 16 ultracompact (UC) HII regions with extended envelopes. The molecular clouds are the ones that give birth to rich stellar clusters and/or very massive (O7–O4) stars. Our data show that the clouds are very clumpy and of irregular morphology. They usually have much larger masses, velocity dispersions, and fractions of dense gas than molecular clouds that form early B or late O stars. This is compatible with earlier findings that more massive stars form in more massive cores. The IR luminosity-to-mass ratio has a mean value of  $9 L_{\odot}/M_{\odot}$  and is little correlated with the cloud mass. Most molecular clouds have star formation efficiencies (SFE's) of 1%–2%. We find size-linewidth and size-density relations in the forms of  $\Delta v \propto D^{0.4}$  and  $n(\text{H}_2) \propto D^{-1.2}$ .  $^{13}\text{CO}$  cores are in general associated with compact HII regions regardless of the presence of UC HII regions therein. In contrast, CS cores are preferentially associated with compact HII regions that contain UC HII regions. As with the fact that the compact HII regions containing UC HII regions are more compact than those not associated with UC HII regions, these indicate that the former may be in an earlier evolutionary phase than the latter. The diffuse extended envelopes of HII regions often develop in the direction of decreasing molecular gas density. Based on detailed comparison of molecular line data with radio continuum and recombination line data, the extended ionized envelopes are likely the results of champagne flows in at least 10 sources in our sample. Together these results appear to support a published suggestion that the extended emission around UC HII regions can be naturally understood by combining the champagne flow model with the hierarchical structure of molecular clouds, taking into account various inclinations and low resolutions of our data. Additionally the blister model seems to be still applicable to most HII regions, even though massive stars usually form in the interiors rather than on the surfaces of molecular clouds. This is possible because massive star-forming clouds have hierarchical structure and irregular morphology.

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# Nonlinear Hydromagnetic Wave Support of a Stratified Molecular Cloud

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We perform numerical simulations of nonlinear MHD waves in a gravitationally stratified molecular cloud that is bounded by a hot and tenuous external medium. We study the relation between the strength of the turbulence and various global properties of a molecular cloud, within a 1.5-dimensional approximation. Under the influence of a driving source of Alfvénic disturbances, the cloud is lifted up by the pressure of MHD waves and reaches a steady-state characterized by oscillations about a new time-averaged equilibrium state. The nonlinear effect results in the generation of longitudinal motions and many shock waves; however, the wave kinetic energy remains predominantly in transverse, rather than longitudinal, motions. There is an approximate equipartition of energy between the transverse velocity and fluctuating magnetic field (as predicted by small-amplitude theory) in the region of the stratified cloud which contains most of the mass; however, this relation breaks down in the outer regions, particularly near the cloud surface, where the motions have a standing-wave character. This means that the Chandrasekhar-Fermi formula applied to molecular clouds must be significantly modified in such regions. Models of an ensemble of clouds show that, for various strengths of the input energy, the velocity dispersion in the cloud  $\sigma \propto Z^{0.5}$ , where  $Z$  is a characteristic size of the cloud. Furthermore,  $\sigma$  is always comparable to the mean Alfvén velocity of the cloud, consistent with observational results.

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Preprint at [www.astro.uwo.ca/~basu/pub.html](http://www.astro.uwo.ca/~basu/pub.html) (high-res figures) or [astro-ph/0306473](http://astro-ph/0306473) (low-res)

# HST/NICMOS Observations of the Embedded Cluster in NGC 2024: Constraints on the IMF and Binary Fraction

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We present an analysis of NICMOS observations of the embedded cluster associated with NGC 2024. An analysis of the cluster color-magnitude diagram (CMD) using the models of D’Antona & Mazzitelli (1997) and Baraffe et al. (1998) indicates that the ratio of intermediate mass (1.0 to 10.0  $M_{\odot}$ ) to low mass (0.1 to 1.0  $M_{\odot}$ ) stars is consistent with the stellar initial mass function (IMF) for the field. In addition to the CMD analysis, we present results on the multiplicity of stars in the region. Three companions (in a sample of 95 potential primaries) were found, with angular separations between 0".4 and 1".0, translating to a projected linear separation of 184 AU to 460 AU for an estimated distance of 460 pc. The completeness of binary detections is assessed using recovery fractions calculated by a series of tests using artificially generated companions to potential primaries in the data frames. We find that the binary fraction in NGC 2024 is consistent with that of Duquennoy & Mayor (1991) for solar neighborhood stars over the range of separations and companion masses appropriate for our survey.

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# Collimation of a Central Wind by a Disc-Associated Magnetic Field

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Studies of jets from young stellar objects (YSO’s) suggest that material is launched from a small central region at wide opening angles and collimated by an interaction with the surrounding environment. Using time-dependent, numerical magnetohydrodynamic simulations, we follow the detailed launching of a central wind via the coupling of a stellar dipole field to the inner edge of an accretion disc. Our method employs a series of nested computational grids, which allows the simulations to follow the central wind out to scales of tens of AU, where it may interact with its surroundings. The coupling between the stellar magnetosphere and disc inner edge has been known to produce an outflow containing both a highly collimated jet plus a wide-angle flow. The jet and wide-angle wind flow at roughly the same speed (100–200 km s<sup>-1</sup>), and most of the energy and mass is carried off at relatively wide angles. We show that the addition of a weak disc-associated field ( $\ll 0.1$  Gauss) has little effect on the wind launching, but it collimates the entire flow (jet + wide wind) at a distance of several AU. The collimation is inevitable, regardless of the relative polarity of the disc field and stellar dipole, and the result is a more powerful and physically broader collimated flow than from the star-disc interaction alone. Within the collimation region, the morphology of the large-scale flow resembles a pitchfork, in projection. We compare these results with observations of outflows from YSO’s and discuss the possible origin of the disc-associated field.

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# Constraints on the disk geometry of the T Tauri star AA Tau from linear polarimetry

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We have simultaneously monitored the photometric and polarimetric variations of the Classical T Tauri star AA Tau during the fall of 2002. We combine these data with previously published polarimetric data covering two earlier epochs. The phase coverage is complete, although not contiguous. AA Tau clearly shows cyclic variations coupled with the rotation of the system. The star-disk system produces a repeatable polarisation curve where the polarisation increases with decreasing brightness. The data fit well with the model put forward by Bouvier et al. (1999) where AA Tau is viewed almost edge-on and its disk is actively dumping material onto the central star via magnetospheric accretion. The inner edge of the disk is deformed by its interaction with the tilted magnetosphere, producing “eclipses” as it rotates and occults the photosphere periodically. From the shape of the polarisation curve in the QU-Plane we confirm that the accretion disk is seen at a large inclination, and predict that its position angle is  $PA \sim 90^\circ$ , i.e., that the disk’s major axis is oriented in the East-West direction.

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## Magellan Echelle Spectroscopy of TW Hydrae Brown Dwarfs

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We present high-resolution optical spectroscopy of four candidate members of the nearby TW Hydrae young association including three brown dwarfs (2MASS 1207-3932, 2MASS 1139-3159 and TWA 5B) and one T Tauri multiple star (TWA 5A). Using echelle spectra from the Magellan Baade 6.5-meter telescope, we confirm the pre-main sequence status and cluster membership of the substellar candidates, through the detection of LiI, NaI consistent with low gravity, and radial velocity. Given their late spectral type ( $\sim M8$ ) and the youth of the association (age  $\sim 10$  Myr), cluster membership certifies these three objects as very low-mass young brown dwarfs. One of them (2MASS 1207-3932) shows strong emission both in the Hydrogen Balmer series ( $H\alpha$  to  $H\epsilon$ ) and in HeI (4471, 5876, 6678 and 7065 Å), compared to other young brown dwarfs of similar spectral type. The  $H\alpha$  line is also relatively broad (10% width  $\sim 200$  km  $s^{-1}$ ) and asymmetric. These characteristics suggest that 2MASS 1207-3932 is a (weak) accretor. While we cannot rule out activity, comparison to a flaring field dwarf implies that such activity would have to be quite anomalous. The verification of accretion would make 2MASS 1207-3932 the oldest actively accreting brown dwarf known to date, suggesting that inner disk lifetimes in substellar objects can be comparable to those in stars, consistent with a similar formation mechanism. Finally, TWA 5A appears to be a variable accretor: observations separated by two days show broad accretion-like  $H\alpha$  (10% width  $\sim 270$  km  $s^{-1}$ ), with significant changes in the  $H\alpha$  profile, as well as in the strengths of HeI, Na D and [OI6300]. TWA 5A is known to be a close triple; thus, our result implies that long-lived disks can exist even in multiple systems.

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## The stellar content of OMC 2/3

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We have revisited the stellar content of OMC 2 and OMC 3 by means of MIR imaging and NIR photometry; in addition, we have extended the existing (sub)mm maps by a huge 1200  $\mu$ m map obtained with SIMBA showing new sources and filamentary features for the first time at that wavelength. The MIR data reveal 43 new sources at  $N$  and  $Q$  which are partly associated with dense condensations at millimetre wavelengths. Six close binary sources could be resolved at

locations where existing (sub)mm maps only show single emission peaks; three of them are classified as early (B-type) systems, one of them is compatible with type K while the remaining two seem to be T Tauri stars. Furthermore, the MIR images indicate the existence of separate circumstellar discs in the K-binary system. NIR colour–colour and colour–magnitude diagrams obtained from 2MASS data are examined to explore the physical properties of the sources and to derive the distribution of  $J$  luminosities. There is a clear decrease in luminosity and thus in stellar mass when going from South to North. Likewise, there is an anti-correlation between Class I and II objects in both regions: while OMC 2 contains twice as much Class II objects compared to Class I, the situation is reversed in OMC 3.

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## Four Probable T Tauri Stars in MBM 12

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Survey observations were carried out in the MBM 12 (sometimes referred to as Lynds 1457) dark cloud in search of H $\alpha$  emission stars by using a slitless grism spectrograph on the 2.6-m reflector of Byurakan Astrophysical Observatory, Armenia. Four new H $\alpha$  stars were detected by the survey and identified as candidate T Tauri stars by follow-up low-dispersion spectroscopy and/or near-infrared photometry.

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## L183 (L134N) Revisited

### I. The very cold core and the ridge

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We report new 1.2 mm continuum observations of the L183 (= L134N) dark cloud with the MAMBO bolometer array at IRAM. Combined with ISOCAM and ISOPHOT data at 7 and 200  $\mu$ m, this new observation is not compatible with the results found by Ward-Thompson et al. (Ward-Thompson D., Scott P.F., Hills R.E., Andr e P. 1994, MNRAS 268, 276) with SCUBA and further analysed by Lehtinen et al. (Lehtinen K., Mattila K., Lemke D., et al. 2003, A&A 398, 571) using ISOPHOT data. Only one bright core, with a northern elongation (the ridge) is detected. We show that this core has an average temperature  $T \approx 7.6 \text{ K} \pm 0.5 \text{ K}$ . This is still an upper limit to the inner core temperature and thus L183 holds one of the coldest cores reported so far.

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[http://aramis.obspm.fr/pagani/l183\\_l1.ps](http://aramis.obspm.fr/pagani/l183_l1.ps)

## Near-IR [Fe II] emission diagnostics applied to cold disk winds in young stars

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We investigate the emissivity properties of the main near-IR transitions of the Fe<sup>+</sup> ion in the conditions prevailing in the inner regions of jets from young stars, based on a simplified 16-level atom model. We present new diagnostic diagrams involving prominent near-IR line ratios that allow to constrain the electronic density, temperature, and Fe gas phase abundance ratio, independently of the heating process. Comparison with recent near-IR observations of a sample of HH objects indicates gas phase Fe abundances ranging from 15–50 % up to 100 % of the solar value (depending on the assumed temperature and on the HH object) in agreement with the moderate depletions previously derived from optical line ratios or shock models. Hence, it appears that Fe-bearing dust is efficiently destroyed in stellar jets. We then use our Fe<sup>+</sup> emissivity model to predict near-IR [Fe II] emission maps for self-similar, cold MHD disk wind models. We show that near-IR [Fe II] lines are stronger than [S II]  $\lambda$ 6731 and [O I]  $\lambda$ 6300 in the cool regions ( $T \leq 7000$  K) near the wind base, and that observations in [Fe II] with AMBER on the VLTI could severely constrain the MHD solution and the inner launch radius of the jet. We also confront theoretical predictions with recent observations in the near-IR [Fe II] lines of the L1551-IRS5 and DG Tau jets. The cold disk wind model reproduces well the two velocity components observed at -100 and -300 km s<sup>-1</sup>. However, it predicts too little emission at low-velocity and insufficient densities. Similar problems were encountered in previous model comparisons in the optical range with jets from T Tauri stars. Denser disk winds with stronger heating at the jet base, which have been invoked for optical jets, also appear needed in younger, embedded Class I jet sources.

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## Constraints on the IMF and the brown dwarf population of the young cluster IC 348

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We use a deep near-infrared census of the young stellar cluster IC 348 to construct and analyze its luminosity function. Our mosaic image of IC 348 covers the full extent of the cluster with a completeness limit of  $J \sim 19.5$  and is therefore sensitive for 2 Myr old cluster members with masses as low as  $M \geq 0.005 M_{\odot}$  for the mean extinction of the known cluster members ( $A_V \sim 3.5$  mag). By using information on stellar ages, extinctions, and the binary population in IC 348 from several recent studies, we can derive statistical constraints on the stellar and sub-stellar mass function of the cluster by modeling the observed luminosity function. We find that the stellar part of the mass function in IC 348 is well described by the galactic field star IMF. While several brown dwarfs have recently been identified in IC 348, our data show that the cluster harbors only a relatively small population of sub-stellar objects. We find that brown dwarfs in the mass range  $0.02-0.075 M_{\odot}$  constitute at most  $\sim 10\%$  of the total cluster population, in contrast to recent results suggesting much larger brown dwarf populations in other young clusters and also the galactic field. Our results suggest that IC 348 has  $\sim 2\times$  fewer brown dwarfs than the Orion Trapezium cluster. A similar brown dwarf “deficit” was recently found in the Taurus star forming region. We speculate about the possible causes for this result, including the presence or absence of nearby massive stars and their influence on the formation of low-mass young stellar objects.

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Preprints are available at <http://www.mpifr-bonn.mpg.de/staff/tpreibis/publications.html> (paper # 35)

## **Blowout from IC1396N: The Emergence of Herbig-Haro Flows from a Cloud Core**

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We have identified a major Herbig-Haro flow, HH 777, which is bursting out of the IC1396N cometary cloud core. Near- and mid-infrared images reveal a very red object embedded in the center of the core, located on the symmetry axis of the large HH 777 flow, suggesting that this is likely the driving source. The projected separation of the working surface from the source is 0.6 pc. An additional 0.4 pc to the east of the source and on the flow axis there is a faint previously known HH object (HH 594) which may be part of the counterflow. It thus appears that we are seeing a blowout of a parsec-scale flow into the surrounding HII region. We study numerical simulations of a jet breaking out of a neutral cloud into a photoionized medium, and reproduce the main features of the HH 777 flow.

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[http://www.ifa.hawaii.edu/publications/preprints/Reipurth\\_03-49.pdf](http://www.ifa.hawaii.edu/publications/preprints/Reipurth_03-49.pdf)

## **Multisite observations of the PMS $\delta$ Scuti star V351 Ori**

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We present the results of multisite observations spanning two years on the pre-main-sequence (PMS) star V351 Ori. A total of around 180 hours of observations over 29 nights have been collected, allowing us to measure five different periodicities, most likely related to the  $\delta$  Scuti variability of V351 Ori. Comparison with the predictions of linear nonadiabatic radial pulsation models put stringent constraints on the stellar parameters and indicate that the distance to V351 Ori is intermediate between the lower limit measured by Hipparcos (210 pc) and that of the Orion Nebula (450 pc). However, radial pulsation models are unable to reproduce all of the observed frequencies with a single choice of ( $M_*$ ,  $L_*$ , and  $T_{\text{eff}}$ ), suggesting the presence of additional nonradial modes.

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## **Small Scale Structure of Low Density Gas in a Dark Cloud Envelope: Kinematic Evidence for Phase Transition?**

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Extensive and sensitive strip-scan observations of the southeastern envelope of Heiles Cloud 2 in Taurus were carried

out in  $^{12}\text{CO } J = 1 - 0$  emission with an angular resolution of 15 arcsec, or 0.010 pc at 140 pc. We discovered in the cloud envelope a number of small scale structures with large linewidths, while in the main body of the cloud relatively narrow linewidth and small velocity gradient was observed. The typical size and linewidth of the small scale features in the cloud envelope is 0.1 pc and  $2 \text{ km s}^{-1}$ , respectively. This linewidth is among the largest of this size observed in non-star-forming regions and even larger than high-mass cores of comparable size. Most of them have low gas density ( $\leq 10^2 \text{ cm}^{-3}$ ) and sizes significantly smaller than their corresponding Jeans lengths, and seem stable under external pressure at a level of  $10^{3-4} \text{ K cm}^{-3}$ . These features may be evidence for structure formation through thermal instability.

In the cloud envelope, there exist small features with large peak-to-peak separation of velocity centroid ( $\sim 7 \text{ km s}^{-1}$ ) but they suddenly disappear in regions with  $A_V \geq 1$ . This sudden change of velocity structure may be due to the gas phase transition from two-phase (WNM+CNM) to single CNM phase.

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<ftp://ftp.nro.nao.ac.jp/nroreport/no587.pdf>

## Submillimeter continuum observations of NGC 7538

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We present high resolution millimeter and sub-millimeter maps (1.3 mm, 850, 800, 450, and 350  $\mu\text{m}$ ) of the molecular cloud south-east of NGC 7538 obtained on the IRAM 30 m telescope at Pico Veleta, Spain and the 15 m James Clerk Maxwell Telescope on Mauna Kea, Hawaii. These maps show filamentary dust ridges extending from and connecting to the three major activity centers (IRS 1-3, NGC 7538 S, and IRS 9) in this high-mass star forming cloud. In addition to the three already known star formation centers we also find a fainter extended submillimeter source near the 20  $\mu\text{m}$  source IRS 4 at the boundary of the optical H II region.

Our high spatial resolution images resolve the young hypercompact H II region IRS 1, and show that it coincides with a compact ( $< 10''$ ) elliptical dust source with a mass of  $\geq 70 M_{\odot}$ . It is surrounded by a cluster of submillimeter sources, none of which have near- or mid-IR counterparts. Three of the sub-millimeter sources are associated with  $\text{H}_2\text{O}$  masers, suggesting that protostars or young stars have formed in these cloud cores.

We find IRS 9 to be an extended elliptical source with a size of  $13'' \times 6''$  at a position angle of  $-80^\circ$  with a second fainter, but more extended source about  $20''$  south of it. The mass of the IRS 9 sub-millimeter source is  $\sim 150 M_{\odot}$ , while the southern source has a mass of  $\sim 90 M_{\odot}$ .

The third activity center, NGC 7538 S, is  $\sim 80''$  south of IRS 1. Here we find a strong elliptical sub-millimeter source of  $12'' \times 7''$  with a position angle of  $58^\circ$ . This source coincides with an OH and  $\text{H}_2\text{O}$  maser and a faint VLA 6 cm source, but shows no near or mid infrared emission. We find NGC 7538 S to have all the characteristics of a Class 0 source, i.e. it is a high mass protostar. It is cold,  $T_d \sim 35 \text{ K}$ , has a disk-like geometry, drives an very young outflow and is extremely massive,  $M \sim 400 M_{\odot}$ . Yet it has a luminosity of only  $10^4 L_{\odot}$ .

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## Dynamical Masses of Young Stars in Multiple Systems

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We present recent measurements of the orbital motion in the young binaries DF Tau and ZZ Tau, and the hierarchical triple Elias 12, that were obtained with the Fine Guidance Sensors on the HST and at the Keck Observatory using adaptive optics. Combining these observations with previous measurements from the literature, we compute preliminary orbital parameters for DF Tau and ZZ Tau. We find that the orbital elements cannot yet be determined

precisely because the orbital coverage spans only  $\sim 90^\circ$  in position angle. Nonetheless, the range of possible values for the period and semi-major axis already defines a useful estimate for the total mass in DF Tau and ZZ Tau, with values of  $(0.90_{-0.35}^{+0.85}) M_\odot$  and  $(0.81_{-0.25}^{+0.44}) M_\odot$ , respectively, at a fiducial distance of 140 pc.

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## A search for $H_2$ around pre-main-sequence stars

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We present the results of a search for pure rotational molecular hydrogen emission from two pre-main-sequence stars, AB Aur and CQ Tau. Observations were made using MICHELLE, the mid-IR echelle spectrometer at the UK Infrared Telescope. We found some evidence for emission in the  $J = 4 \rightarrow 2$  line in AB Aur, but no  $J = 3 \rightarrow 1$  line from either star. We derive upper limits on line flux which are significantly smaller than previous line flux estimates based on *ISO* observations. This suggests that the emission detected by *ISO* is extended on scales of at least 6 arcsec, and does not come from the disk as previously thought.

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## A Deep *Chandra* X-ray Observation of the Embedded Young Cluster in NGC 2024

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We present results of a sensitive 76 ksec *Chandra* observation of the young stellar cluster in NGC 2024, lying at a distance of  $\sim 415$  pc in the Orion B giant molecular cloud. Previous infrared observations have shown that this remarkable cluster contains several hundred embedded young stars, most of which are still surrounded by circumstellar disks. Thus, it presents a rare opportunity to study X-ray activity in a large sample of optically invisible protostars and classical T Tauri stars (cTTS) undergoing accretion. *Chandra* detected 283 X-ray sources of which 248 were identified with counterparts at other wavelengths, mostly in the near-infrared. Astrometric registration of *Chandra* images against the Two Micron All Sky Survey (2MASS) resulted in positional offsets of  $\approx 0.25''$  near field center, yielding high confidence identifications of infrared counterparts. The *Chandra* detections are characterized by hard heavily-absorbed spectra and spectacular variability. Spectral analysis of more than 100 of the brightest X-ray sources yields a mean extinction  $\langle A_V \rangle \sim 10.5$  mag and typical plasma energies  $\langle kT \rangle \sim 3$  keV. The range of variability includes rapid impulsive flares and persistent low-level fluctuations indicative of strong magnetic activity, as well as slow rises and falls in count rate whose origin is more obscure. Some slowly-evolving outbursts reached sustained temperatures of  $kT \sim 6 - 10$  keV. *Chandra* detected all but one of a subsample of 27 cTTS identified from previous near and mid-IR photometry, and their X-ray and bolometric luminosities are correlated. We also report the X-ray detection of IRS 2b, which is thought to be a massive embedded late O or early B star that may be the ionizing source of NGC 2024. Seven millimeter-bright cores (FIR 1-7) in NGC 2024 that may be protostellar were not detected, with the possible exception of faint emission near the unusual core FIR-4.

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## Monte Carlo Radiative Transfer in Embedded Prestellar Cores

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We implement a Monte Carlo radiative transfer method, that uses a large number of monochromatic luminosity packets to represent the radiation transported through the system. These packets are injected into the system and interact stochastically with it. We test our code against various benchmark calculations and determine the number of packets required to obtain accurate results under different circumstances. We then use this method to study cores that are directly exposed to the interstellar radiation field (non-embedded cores). Our code predicts temperature and intensity profiles inside these cores which are in good agreement with previous studies using different radiative transfer methods.

We also explore a large number of models of cores that are embedded in the centre of a molecular cloud. We study cores with different density profiles embedded in molecular clouds with various optical extinctions and we calculate temperature profiles, SEDs and intensity profiles. Our study indicates that the temperature profiles in embedded cores are less steep than those in non-embedded cores. Deeply embedded cores (ambient cloud with visual extinction larger than 15-25) are almost isothermal at around 7-8 K. The temperature inside cores surrounded by an ambient cloud of even moderate thickness ( $A_V \sim 5$ ) is less than 12 K, which is lower than previous studies have assumed. Thus, previous mass calculations of embedded cores (for example in the  $\rho$  Ophiuchi protocluster), based on mm continuum observations, may underestimate core masses by up to a factor of 2.

Our study shows that the best wavelength region to observe embedded cores is between 400 and 500  $\mu\text{m}$ , where the core is quite distinct from the background. We also predict that very sensitive observations ( $\sim 1 - 3 \text{ MJy sr}^{-1}$ ) at 170-200  $\mu\text{m}$  can be used to estimate how deeply a core is embedded in its parent molecular cloud. The upcoming *Herschel* mission (ESA, 2007) will, in principle, be able to detect these features and test our models.

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## Late B-type stars and their candidate companions resolved with Chandra

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We present the first results from a series of *Chandra* observations carried out with the aim to examine the origin of X-ray emission in main-sequence late B-type stars. No X-ray emission is expected from these objects on theoretical grounds. We use high spatial resolution X-ray observations to enlighten the prevalent speculation that previously unknown late-type or low-mass companion stars are the sites of the X-ray emission, instead of the B-type stars themselves. As the contraction timescale for a late-type star to the main-sequence is longer than the main-sequence lifetime of an early-type star such companions should be pre-main sequence stars.

Adaptive optics observations have recently revealed faint objects near a substantial number of B-type stars detected in X-rays during the *ROSAT* All-Sky Survey. We selected those with a separation of  $1 - 6''$  for imaging with *Chandra*. Here we present and discuss the results for HD1685, HD113703, HD123445, HD133880, and HD169978. Four of the new infrared objects show infrared colors and magnitudes typical for low-mass pre-main sequence stars, and are likely true companions to the 10-50 Myr old B-type stars. These multiple systems are now resolved for the first time in X-ray light.

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<http://www.astropa.unipa.it/~stelzer/publications.html>

# Ten Million Degree Gas in M 17 and the Rosette Nebula: X-ray Flows in Galactic HII Regions

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We present the first high-spatial-resolution X-ray images of two high-mass star forming regions, the Omega Nebula (M 17) and the Rosette Nebula (NGC 2237–2246), obtained with the *Chandra X-ray Observatory* Advanced CCD Imaging Spectrometer (ACIS) instrument. The massive clusters powering these HII regions are resolved at the arcsecond level into >900 (M 17) and >300 (Rosette) stellar sources similar to those seen in closer young stellar clusters. However, we also detect soft diffuse X-ray emission on parsec scales that is spatially and spectrally distinct from the point source population. The diffuse emission has luminosity  $L_x \simeq 3.4 \times 10^{33}$  ergs s<sup>-1</sup> in M 17 with plasma energy components at  $kT \simeq 0.13$  and  $\simeq 0.6$  keV (1.5 and 7 MK), while in Rosette it has  $L_x \simeq 6 \times 10^{32}$  ergs s<sup>-1</sup> with plasma energy components at  $kT \simeq 0.06$  and  $\simeq 0.8$  keV (0.7 and 9 MK). This extended emission most likely arises from the fast O-star winds thermalized either by wind-wind collisions or by a termination shock against the surrounding media. We establish that only a small portion of the wind energy and mass appears in the observed diffuse X-ray plasma; in these blister HII regions, we suspect that most of it flows without cooling into the low-density interstellar medium. These data provide compelling observational evidence that strong wind shocks are present in HII regions.

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## Determination of the gas-to-dust ratio in nearby dense clouds using X-ray absorption measurements

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We present a comparison of the gas and dust properties of the dense interstellar matter in six nearby star-forming regions ( $d < 500$  pc):  $\rho$  Oph, Cha I, R CrA, IC 348, NGC 1333, and Orion. We measure from *Chandra* and *XMM-Newton* observations the X-ray absorption toward pre-main sequence stars (PMS) without accretion disks (i.e., Class III sources) to obtain the total hydrogen column density  $N_{\text{H,X}}$ . For these sources we take from the literature the corresponding dust extinction in the near-infrared,  $A_{\text{J}}$ , or when unavailable we derive it from SED fitting using the available *DENIS*, *2MASS*, *ISOCAM* and other data. We then compare  $N_{\text{H,X}}$  and  $A_{\text{J}}$  for each object, up to unprecedently high extinction. For the  $\rho$  Oph dark cloud with a relatively large sample of 20 bona-fide Class III sources, we probe the extinction up to  $A_{\text{J}} \leq 14$  ( $A_{\text{V}} \leq 45$ ), and find a best-fit linear relation  $N_{\text{H,X}}/A_{\text{J}} = 5.6 (\pm 0.4) \times 10^{21}$  cm<sup>-2</sup> mag<sup>-1</sup>, adopting standard ISM abundances. The other regions reveal a large dispersion in the  $N_{\text{H,X}}/A_{\text{J}}$  ratio for each source but for lack of adequate IR data these studies remain limited to moderate extinctions ( $A_{\text{J}} \leq 1.5$  or  $A_{\text{V}} \leq 5$ ). For  $\rho$  Oph, the  $N_{\text{H,X}}/A_{\text{J}}$  ratio is significantly lower ( $\geq 2\sigma$ ) than the galactic value, derived using the standard extinction curve ( $R_{\text{V}} = 3.1$ ). This result is consistent with the recent downwards revision of the metallicity of the Sun and stars in the solar vicinity. We find that the  $\rho$  Oph dense cloud has the same metallicity than the *local* ISM when assuming that the galactic gas-to-dust ratio remains unchanged. The difference between galactic and local values of the gas-to-dust ratio can thus be attributed entirely to a difference in metallicity.

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## A spectral survey of the star forming core of the Orion Nebula from 455 – 507 GHz

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The results of a submillimetre wavelength spectral line survey between 455.1 – 507.4 GHz of the star-forming core of the Orion-KL hot cloud are reported. A total of 254 lines were detected to a main beam brightness temperature sensitivity  $T_{mb} \sim 1 - 3$  K. The detected lines are identified as being associated with 30 different molecular species or their isotopomeric variants. The strongest line detected was the  $J = 4-3$  transition of the CO molecule. Apart from abundant diatomic rotors such as CO and CS, the spectrum is dominated by SO, SO<sub>2</sub> and CH<sub>3</sub>OH and large organic molecules such as (CH<sub>3</sub>)<sub>2</sub>O, CH<sub>3</sub>CN, C<sub>2</sub>H<sub>3</sub>CN, C<sub>2</sub>H<sub>5</sub>CN and HCOOCH<sub>3</sub> which make up  $\sim 72\%$  of the total number of lines; unidentified lines  $\sim 13\%$ ; and other lines the remaining  $\sim 15\%$  of the total. Rotational temperatures and column densities derived using standard rotation diagram analysis techniques were found to range from 70 - 300 K, and  $10^{14} - 10^{17}$  cm<sup>2</sup> respectively.

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<http://star.kent.ac.uk/gjw/h3757.ps>

## Disks around the Young Stars TW Hya and HD 100546 Imaged at 3.4 Millimeters with the Australia Telescope Compact Array

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We present observations of the young stars TW Hya and HD 100546 made with the Australia Telescope Compact Array at 89 GHz with  $\sim 2''$  resolution and  $\sim 3$  mJy continuum sensitivity. Compact thermal dust continuum emission is detected from disks surrounding both stars. HD 100546 also shows hints of extended emission, presumably a residual protostellar envelope, which is also visible in scattered light at optical wavelengths. For TW Hya, HCO<sup>+</sup> J=1–0 line emission from the circumstellar disk is detected and spatially resolved. The observed size and intensity are in good agreement with model calculations based on an irradiated disk with substantial depletions derived previously from single dish observations of higher-J HCO<sup>+</sup> transitions.

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## Indications of Inflow Motions in Regions Forming Massive Stars

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Observational evidence for inflowing motions in massive star forming regions has been extremely rare. We have made a spectroscopic survey of a sample of 28 massive star forming cores associated with water masers. An optically thick line of HCN (3–2) was used in combination with optically thin lines [ $\text{H}^{13}\text{CN}$  (3–2) or  $\text{C}^{34}\text{S}$  (5–4), (3–2), and (2–1)], to identify “blue” line profiles that can indicate inflow. Comparing intensities for 18 double-peaked line profiles yields 11 blue and 3 red profiles that are statistically significant. In the full sample of 28 sources, 12 show blue profiles and 6 show red profiles that are statistically significant based on the velocity offsets of lines that are optically thick from those that are optically thin. These results indicate that HCN (3 – 2) emission may trace inflow in regions forming high-mass stars.

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## High-Latitude Molecular Clouds in an HI Filament toward MBM 53, 54, and 55 Complex; Existence of $\text{H}_2$ Cloud with Low-CO Intensity

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We carried out a CO survey of high galactic latitude molecular clouds toward an HI filament that contains a molecular cloud complex, MBM 53, 54, and 55, with the NANTEN telescope. Our observation covered the whole area of the HI filament in  $^{12}\text{CO}$  ( $J = 1-0$ ) with a  $4'$  grid spacing. The filament is found to consist of a number of clumpy molecular clouds, and we identified 110  $^{12}\text{CO}$  clouds in the region, whose total mass is estimated to be  $\sim 1200 M_{\odot}$ .  $^{13}\text{CO}$  ( $J = 1-0$ ) observations were carried out toward the region of high  $^{12}\text{CO}$  intensities in order to measure the optical depth of molecular gas. There is no detection in  $\text{C}^{18}\text{O}$  ( $J = 1-0$ ) line in the observed region, indicating that there are no clouds dense enough to form stars in the near future. These observations spatially resolved the entire gas distribution of MBM 53, 54, and 55 for the first time, and we have found a massive cloud, HLCG 92–35, around  $(l, b) \sim (92^{\circ}, -35^{\circ})$  whose mass is  $\sim 330 M_{\odot}$ , corresponding to  $\sim 1/4$  of the total mass. This CO cloud occupies a galactic western half of a circular HI cloud toward  $(l, b) = (93^{\circ}.5, -35^{\circ}.5)$ , and the HI to CO mass ratio is estimated to be the largest in the observed region. The far-infrared excess over HI emission, which is a good indicator of an existence of molecular hydrogen, toward HLCG 92–35 is the largest in the observed region. The ratio of the luminosity of the infrared excess to CO mass is also significantly larger than those of the other clouds by a factor of  $\sim 5$ . These facts indicate that HLCG 92–35 is a CO-forming molecular cloud, which is younger than the MBM clouds in terms of molecular cloud formation. Some past explosive event has been suggested by Gir et al. (1994) toward the HI filament. Toward HLCG 92–35, the molecular gas distributed along the western edge of the HI cloud, which implies that the molecular gas may be formed by a compression of expanding HI shell.

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<http://www.a.phys.nagoya-u.ac.jp/~hiro/paper.pdf>

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