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## *Abstracts of recently accepted papers*

### **A molecular jet from SVS 13B near HH 7–11**

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We present interferometric images of the  $\lambda$  1.3 and 3.5 mm continuum and the SiO  $J = 2 \rightarrow 1$  emission towards the SVS 13/HH 7–11 vicinity. The continuum data resolve SVS 13 into two components separated by  $14''.5$  ( $\sim 4300$  AU) and having very similar millimeter properties: each of them has about  $1 M_{\odot}$  of circumstellar material and its emission is characterized by a spectral index of  $\sim 2.5$ . One of the components, SVS 13B, lacks optical, near infrared, or cm-wave counterpart, and is only detectable at millimeter waves, a fact that suggests it represents an extremely embedded, Class 0 object. This source, in addition, powers a remarkably collimated molecular outflow as seen by a high velocity SiO jet. HH 12, HH 16, and HH 352 lie along the line of this jet, suggesting they are also excited by SVS 13B. Our observations highlight the star-formation richness of the HH 7–11 region which contains in a small area some of the youngest and most extraordinary outflows known.

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### **Multiple CO Outflows in Circinus: The Churning of a Molecular Cloud**

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We present a millimeter wave study of a cluster of bipolar CO outflows embedded in the western end of the Circinus molecular cloud complex, G317-4, that is traced by very high optical extinction. For an assumed distance of 700 pc, the entire Circinus cloud is estimated to have a mass of about  $5 \times 10^4 M_{\odot}$ . The opaque western portion that was mapped in this study has a mass of about  $10^3 M_{\odot}$ , contains a number of embedded infrared sources and various compact 1.3 mm continuum sources, and has a remarkable filamentary structure with numerous cavities which appears to be the fossil remnants of past star formation activity. The most active star forming region in this part of Circinus is centered around a compact cluster of millimeter continuum sources associated with IRAS 14564–6254 and IRAS 14563–6301 which lies about  $7'$  to the south. This region contains two known Herbig-Haro objects, HH 76 and HH 77, and a profusion of overlapping high velocity CO outflow lobes. Among these, we can clearly distinguish the two largest outflows in Circinus (flows A and B) which appear to originate from the two brightest IRAS sources. This region also contains at least two other prominent but overlapping bipolar CO outflows (flows C and C'), one of which may be associated with IRAS14564–6258. Two compact and relatively low velocity CO outflows lie at the northern

periphery of the Circinus core and are associated with IRAS 14563–6250 (flow E), a source also detected as a 1.3 mm continuum source, and with IRAS 14562–6248 (flow G). A small but prominent reflection nebula associated with the nebulous star vBH65a and a co-axial Herbig-Haro jet, HH 139, is located at the southeastern edge of this cloud core and illuminates part of a cavity seen as a low extinction region. A faint and low mass CO molecular flow is associated with vBH65a and HH 139 (flow F). The infrared source IRAS 14580–6303 drives a small CO flow (flow I). A second, active center of star formation is centered on the source IRAS 14592–6311, the peculiar Herbig Ae/Be star vBH65b, about 20' to the southeast of the main cloud core; four HH objects, HH 140 to HH 143, and a compact CO outflow are located here (flow D). About 5' further south, IRAS 14596–6320 drives yet another outflow (flow H). Thus, the mapped portion of Circinus contains at least 10 CO emitting molecular outflows. Assuming that star formation has continued at a steady rate for the last several hundred thousand years, the Circinus cloud is expected to have produced dozens of young stars. Their outflows have severely altered the structure and kinematics of this cloud as evidenced by the multitude of prominent cavities and dust filaments that outline their boundaries. This level of star formation activity is consistent with the numerous post-outflow phase H $\alpha$  emission line stars that have been found in this region. The Circinus cloud complex is an archetypical case where star formation activity may have profoundly affected the structure of a molecular cloud, producing its strikingly filamentary and cavitated appearance and providing further evidence that star formation may be a self regulated process.

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## Collapse of a Molecular Cloud Core to Stellar Densities: The First Three-Dimensional Calculations

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We present results from the first three-dimensional calculations ever to follow the collapse of a molecular cloud core ( $\sim 10^{-18}$  g cm $^{-3}$ ) to stellar densities ( $> 0.01$  g cm $^{-3}$ ). The calculations resolve structures over 7 orders of magnitude in spatial extent ( $\sim 5000$  AU –  $0.1 R_{\odot}$ ), and over 17 orders of magnitude in density contrast. With these calculations, we consider whether fragmentation to form a close binary stellar system can occur during the second collapse phase. We find that, if the quasistatic core that forms before the second collapse phase is dynamically unstable to the growth of non-axisymmetric perturbations, the angular momentum extracted from the central regions of the core, via gravitational torques, is sufficient to prevent fragmentation and the formation of a close binary during the subsequent second collapse.

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## Near Infrared Imaging of Star Forming Region AFGL 5157

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We present near infrared images of the star forming region AFGL 5157 in the JHK' broad-band filters and H $_2$  v=1-0 S(1) narrow-band filter. The images reveal a dense cluster of stars and infrared nebulosities associated with the previously known infrared sources. Of 54 near infrared sources detected in the nebula, NGC 1985, twelve exhibit infrared excesses typical of T Tauri stars, Herbig Ae/Be stars, and protostars. The magnitude and color distribution of the cluster of stars in the nebula are found to be different from those outside the nebular region. The K'-magnitude distribution of the cluster is quite flat while the non-cluster is peaked toward the low-magnitude. The [H-K'] color of the cluster also displays 0.3 mag redder than that of the non-cluster. The infrared nebula displays a bright nucleus with two spirals extended to the north and south. In light of color properties of the nebula, we propose a shell model for the nebular structure which could be formed by star forming activity of the central cluster. Many sources with infrared excesses are found to be embedded in the shell structure.

Twelve shocked knots in H<sub>2</sub> emission are observed in the region. The non-axially symmetric distribution of the knots indicates the presence of multiple outflows in the region. Although we failed to identify the powering sources responsible for some of the HH-like objects, the relationship of the H<sub>2</sub> emission with infrared sources shows that there must be several spatially separated sources exciting the shocked H<sub>2</sub> emission, as well as the previously observed H<sub>2</sub>O masers and molecular outflow. Diffuse H<sub>2</sub> emission is also detected on the shell structure, which supports the shell model of the nebula. This diffuse emission could result from fluorescence by relatively evolved stars in the cluster.

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## Proper motions and variability of the H<sub>2</sub> knots in the HH 111 and HH 121 protostellar outflows.

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The proper motions of molecular hydrogen knots in the HH 111 and HH 121 outflows have been measured. High tangential velocities, in the range 265–461 km s<sup>-1</sup>, are measured in both flows. These values exceed the dissociation speed limit for molecular hydrogen in shocks, and therefore indicate that the associated shock velocities are much lower than the shock pattern speeds and underlying jet speeds. The data seemingly support a variable flow velocity origin for the knots in the two outflows, though some of the knots could also be caused by Kelvin-Helmholtz instabilities. We also report on the marked variability in morphology and luminosity observed in a number of these knots. A molecular cooling time of the order of a few years is inferred, in line with theoretical predictions based on “typical” jet densities and velocities.

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Preprints available from: <http://www.jach.hawaii.edu/~cdavis/papers.html>

## The Magnetic Field of the NGC 2024 Molecular Cloud

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We have carried out Very Large Array (VLA) Zeeman observations of absorption lines of H I and OH toward the molecular cloud associated with the NGC 2024 (Orion B) H II region. The synthesized beam diameters are 68'' × 52'',  $pa = 38^\circ$  and 81'' × 65'',  $pa = -6^\circ$  for OH and H I, respectively. The absorption lines could be mapped over the NGC 2024 continuum source, which has an extent (at the 1 Jy beam<sup>-1</sup> level) of  $\Delta\alpha \approx 7'$  by  $\Delta\delta \approx 5'$ . The maps of the magnetic field, together with comparisons with additional data from the published literature, lead to the following conclusions. (1) The magnetic field comes from a line subcomponent at  $v_{LSR} \approx 10.2$  km s<sup>-1</sup> which corresponds in velocity and in spatial morphology with the northern dense molecular ridge in NGC 2024. (2)  $B_{los}$  varies from 0 to the northeast of the northern molecular ridge to almost 100  $\mu$ G to the southwest. The variation in  $B_{los}$  may be due to the field being mainly in the plane of the sky to the northeast but having a significant line-of-sight component to the southwest. (3) Velocities in the cloud are supersonic but approximately equal to the Alfvén velocity, which is consistent with motions being dominated by magnetohydrodynamical waves rather than thermal motion or hydrodynamical turbulence. (4) The mass-to-magnetic flux ratio is supercritical, which suggests that the static magnetic field does not support the cloud against collapse. Simple virial estimates of the relative importance of gravitational, kinetic, and magnetic energies show that the ratio of kinetic/gravitational energy is about 0.5, while the magnetic/gravitational energy ratio is less than 0.1. At face value, these results imply that the cloud is supported mainly by non-thermal motions rather than by the static magnetic field. However, since we only measure directly the line-of-sight component of  $\mathbf{B}$ , this result is not conclusive.

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## The submillimetre colour of YSOs

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A survey is presented of the submillimetre continuum spectra from dust around 73 Young Stellar Objects (YSOs) associated with Herbig-Haro objects and molecular outflows. Spectra at millimetre to submillimetre wavelengths taken with similar beam sizes have been obtained for 42 of the objects, with the remainder either detected or with upper limits at  $800\ \mu\text{m}$ . The data are combined with far-infrared IRAS fluxes, and then compared with published sub-millimetre data from other types of YSO; this results in a dataset of  $\sim 150$  sub-millimetre spectra. We have then employed colour-colour diagrams to investigate the differences in sub-millimetre continuum spectra of different YSO types.

The majority of targets are optically-obscured YSOs (generally Lada Class I); all are found to have a sub-millimetre spectral index ( $\alpha_{mm}$ ) of  $\sim 3.5$ . None of these objects has  $\alpha_{mm} \leq 3.0$ . This is significantly different from published optically-visible T Tauri stars (Class II-III), many of which have  $\alpha_{mm} \sim 2.5$ . The few main-sequence stars so far observed in the submillimetre generally also have a low value of  $\alpha_{mm}$ . We find that objects which might be classified as T Tauri stars, but which are not directly visible, have higher values of  $\alpha_{mm}$ .

Assuming isothermal optically thin dust emission, this implies a dust emissivity index  $\beta$  of  $\sim 1.5$  for embedded objects, and  $\sim 0.5$  for visible objects. The reduced  $\alpha_{mm}$  in low optical extinction sources can be attributed to either grain growth or the formation of a compact optically thick circumstellar disc, and we discuss these two options in light of the new data. If, as the results suggest, large fractal grains are present in the more evolved systems, then these will have higher millimetre mass opacity, implying that the determination of the circumstellar mass evolution from submillimetre continuum fluxes must take into account the evolution of the dust itself.

High-mass embedded YSOs also have spectra very similar to their low-mass counterparts, but with higher dust temperature (again, under the isothermal optically thin assumption). Also most Class 0 YSOs have a high value of  $\alpha_{mm}$ , although three have flatter spectra more typical of fractal dust, which is difficult to explain under simple grain coagulation models.

The submillimetre continuum flux is also compared with the intensity of two molecular lines:  $\text{C}^{18}\text{O}$  J=2-1 and  $\text{H}_2\text{CO}$   $3_{03} - 2_{02}$ . The integrated emission from the higher-density tracer,  $\text{H}_2\text{CO}$ , is well correlated with continuum flux. The  $\text{C}^{18}\text{O}$  line shows a less significant correlation, particularly at low masses, suggesting that this may not be a good molecule to search for low-mass YSOs. By comparing T Tauri stars and younger YSOs with the same continuum flux, we find evidence that T Tauri stars are unusually weak in  $\text{C}^{18}\text{O}$  emission, and we give some possible explanations.

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## Molecular abundance enhancements in the highly collimated bipolar outflow BHR 71

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We report observations of the  $J = 3 \rightarrow 2$  and  $J = 2 \rightarrow 1$  transitions of SiO and CS, the  $J_k = 3_k \rightarrow 2_k$  and  $J_k = 2_k \rightarrow 1_k$  transitions of  $\text{CH}_3\text{OH}$ , and the  $J = 1 \rightarrow 0$  transition of  $\text{HCO}^+$ , made with SEST, toward the highly collimated bipolar

outflow BHR 71. Broad wing emission was detected toward the outflow lobes in all the observed molecular lines. The shape of the profiles are strikingly different from molecule to molecule. For CS and HCO<sup>+</sup> the emission from the outflowing gas appears as a weak broad feature superposed upon a strong narrow emission from the quiescent ambient gas. For CH<sub>3</sub>OH the intensity of the broad emission feature is considerably stronger than that of the narrow component, while for SiO the broad feature completely dominates the emission spectra.

The spatial distribution of the integrated wing emission is considerably extended, and broadly similar in all the observed molecular transitions, showing well separated blue and red shifted lobes with FWHM angular sizes of 2'4 × 1'3 and 2'4 × 1'4, respectively. We find that the abundance of methanol and silicon monoxide in the outflow lobes is enhanced with respect to that of the ambient cloud by factors of up to ~ 40 and 350, respectively. The large enhancements of methanol and silicon monoxide in the outflow lobes are most likely due to the release from grains of ice mantles and Si-bearing species via shocks produced by the interaction between the outflow and dense ambient gas. On the other hand, we find that the abundance of HCO<sup>+</sup> in the outflowing gas is smaller than that in the ambient gas by about a factor of 20, a decrease consistent with theoretical predictions of shock models.

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## The structure of young star clusters

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In this paper we analyse and compare the clustering of young stars in Chamaeleon I and Taurus. We compute the mean surface-density of companion stars  $\bar{N}$  as a function of angular displacement  $\theta$  from each star. We then fit  $\bar{N}(\theta)$  with two *simultaneous* power laws, i.e.  $\bar{N}(\theta) \simeq K_{\text{bin}}\theta^{-\beta_{\text{bin}}} + K_{\text{clu}}\theta^{-\beta_{\text{clu}}}$ . For Chamaeleon I, we obtain  $\beta_{\text{bin}} = 1.97 \pm 0.07$  and  $\beta_{\text{clu}} = 0.28 \pm 0.06$ , with the elbow at  $\theta_{\text{elb}} \simeq 0.011^\circ \pm 0.004^\circ$ . For Taurus, we obtain  $\beta_{\text{bin}} = 2.02 \pm 0.04$  and  $\beta_{\text{clu}} = 0.87 \pm 0.01$ , with the elbow at  $\theta_{\text{elb}} \simeq 0.013^\circ \pm 0.003^\circ$ . For both star clusters the observational data make quite large ( $\sim 5\sigma$ ) systematic excursions from the best fitting curve in the binary regime ( $\theta < \theta_{\text{elb}}$ ). These excursions are visible also in the data used by Larson and Simon, and may be attributable to evolutionary effects of the types discussed recently by Nakajima *et al.* and Bate *et al.* In the clustering regime ( $\theta > \theta_{\text{elb}}$ ) the data conform to the best fitting curve very well, but the  $\beta_{\text{clu}}$  values we obtain differ significantly from those obtained by other workers. These differences are due partly to the use of different samples, and partly to different methods of analysis.

We also calculate the box-dimensions for the two star clusters: for Chamaeleon I we obtain  $D_{\text{box}} \simeq 1.51 \pm 0.12$ , and for Taurus  $D_{\text{box}} \simeq 1.39 \pm 0.01$ . However, the limited dynamic range makes these estimates simply descriptors of the large-scale clustering, and not admissible evidence for fractality.

We propose two algorithms for objectively generating maps of constant stellar surface-density in young star clusters. Such maps are useful for comparison with molecular-line and dust-continuum maps of star-forming clouds, and with the results of numerical simulations of star formation. They are also useful because they retain information which is suppressed in the evaluation of  $\bar{N}(\theta)$ . Algorithm I (*SCATTER*) uses a universal smoothing length, and therefore has a restricted dynamic range, but it is implicitly normalized. Algorithm II (*GATHER*) uses a local smoothing length, which gives it much greater dynamic range, but it has to be normalized explicitly. Both algorithms appear to capture well the features which the human eye sees. We are exploring ways of analyzing such maps to discriminate between fractal structure and single-level clustering, and to determine the degree of central condensation in small- $N$  clusters.

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# Envelope structure of deeply embedded young stellar objects in the Serpens Molecular Cloud

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Aperture-synthesis and single-dish (sub) millimeter molecular-line and continuum observations reveal in great detail the envelope structure of deeply embedded young stellar objects (SMM 1 = FIRS 1, SMM 2, SMM 3, SMM 4) in the densely star-forming Serpens Molecular Cloud. SMM 1, 3, and 4 show partially resolved ( $> 2'' = 800$  AU) continuum emission in the beam of the Owens Valley Millimeter Array at  $\lambda = 3.4$ – $1.4$  mm. The continuum visibilities accurately constrain the density structure in the envelopes, which can be described by a radial power law with slope  $-2.0 \pm 0.5$  on scales of 300 AU to 8000 AU. Inferred envelope masses within a radius of 8000 AU are 8.7, 3.0, and 5.3  $M_{\odot}$  for SMM 1, 3, and 4, respectively. A point source with 20%–30% of the total flux at 1.1 mm is required to fit the observations on long baselines, corresponding to warm envelope material within  $\sim 100$  AU or a circumstellar disk. No continuum emission is detected interferometrically toward SMM 2, corresponding to an upper limit of 0.2  $M_{\odot}$  assuming  $T_d = 24$  K. The lack of any compact dust emission suggests that the SMM 2 core does not contain a central protostar.

Aperture-synthesis observations of the  $^{13}\text{CO}$ ,  $\text{C}^{18}\text{O}$ ,  $\text{HCO}^+$ ,  $\text{H}^{13}\text{CO}^+$ ,  $\text{HCN}$ ,  $\text{H}^{13}\text{CN}$ ,  $\text{N}_2\text{H}^+$  1–0,  $\text{SiO}$  2–1, and  $\text{SO}$  2<sub>2</sub>–1<sub>1</sub> transitions reveal compact emission toward SMM 1, 3, and 4. SMM 2 shows only a number of clumps scattered throughout the primary field of view, supporting the conclusion that this core does not contain a central star. The compact molecular emission around SMM 1, 3, and 4 traces 5''–10'' (2000–4000 AU) diameter cores that correspond to the densest regions of the envelopes, as well as material directly associated with the molecular outflow. Especially prominent are the optically thick  $\text{HCN}$  and  $\text{HCO}^+$  lines which show up brightly along the walls of the outflow cavities.  $\text{SO}$  and  $\text{SiO}$  trace shocked material, where their abundances may be enhanced by 1–2 orders of magnitude over dark-cloud values.

A total of 31 molecular transitions have been observed with the James Clerk Maxwell and Caltech Submillimeter telescopes in the 230, 345, 490, and 690 GHz atmospheric windows toward all four sources, containing, among others, lines of  $\text{CO}$ ,  $\text{HCO}^+$ ,  $\text{HCN}$ ,  $\text{H}_2\text{CO}$ ,  $\text{SiO}$ ,  $\text{SO}$ , and their isotopomers. These lines show 20–30  $\text{km s}^{-1}$  wide line wings, deep and narrow (1–2  $\text{km s}^{-1}$ ) self-absorption, and 2–3  $\text{km s}^{-1}$  FWHM line cores. The presence of highly excited lines like  $^{12}\text{CO}$  4–3 and 6–5,  $^{13}\text{CO}$  6–5, and several  $\text{H}_2\text{CO}$  transitions indicates the presence of material with temperatures  $>_{\sim 100}$  K. Monte-Carlo calculations of the molecular excitation and line transfer show that the envelope model derived from the dust emission can successfully reproduce the observed line intensities. The depletion of  $\text{CO}$  in the cold gas is modest compared to values inferred in objects like NGC 1333 IRAS 4, suggesting that the phase of large depletions through the entire envelope is short-lived and may be influenced by the local star-formation density. Emission in high excitation lines of  $\text{CO}$  and  $\text{H}_2\text{CO}$  requires the presence of a small amount of  $\sim 100$  K material, comprising less than 1% of the total envelope mass and probably associated with the outflow or the innermost region of the envelope. The derived molecular abundances in the warm ( $T_{\text{kin}} > 20$  K) envelope are similar to those found toward other class 0 YSOs like IRAS 16293–2422, though some species appear enhanced toward SMM 1. Taken together, the presented observations and analysis provide the first comprehensive view of the physical and chemical structure of the envelopes of deeply embedded young stellar objects in a clustered environment on scales between 1000 and 10,000 AU.

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## Photodissociation Regions and H II Regions in NGC 6334

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Using the VLA at 8.485 GHz, we have imaged the southern portion of the star-forming ridge of molecular gas in NGC 6334. The diffuse radio source G351.20+0.70, discovered by Moran et al. (1990), is now resolved into a roughly spherical shell of radius  $\sim 1'$  (0.5 pc). The distribution of molecular gas, traced by CO emission, of photodissociated gas, traced by [C II] 158  $\mu\text{m}$  emission, and of ionized gas, traced by radio continuum emission, is precisely that expected for a photodissociation region—the ionized gas lies on the interior of the shell, the photodissociated gas just outside the ionized gas, and the molecular gas just outside the photodissociated gas.

We also detected faint radio counterparts to the strong infrared sources NGC 6334 IV–IRS 20 and NGC 6334 V. If these objects are ZAMS stars, they produce far too little radio free-free emission expected for the observed infrared flux. Some possible explanations for this discrepancy are: (1) the radio free-free emission is optically thick, (2) the stellar ionizing radiation is obscured by dust, (3) the objects are not single OB stars but very compact clusters of later type stars, or (4) the objects are protostars. For both NGC 6334 V and NGC 6334 IV–IRS 20, the radio spectrum for the unresolved sources is inconsistent with optically thick free-free emission or dust obscuration from a homogeneous H II region. The radio spectral index for NGC 6334 IV–IRS 20 is consistent with the value of 0.6 expected for an optically thick H II region for a star undergoing mass loss, but that of NGC 6334 V is not. Because the IR sources in NGC 6334 V are very compact ( $\lesssim 0.02$  pc), the stellar volume densities for a cluster of later-type stars would be unreasonably large. The objects in NGC 6334 V are probably protostars.

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## Interstellar reddening from the Hipparcos and Tycho Catalogues I. Distances to nearby molecular clouds and star forming regions

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The Hipparcos and Tycho Catalogues offer an interesting possibility to study the local distribution of interstellar reddening from the combination of data contained in the catalogues: Hipparcos parallaxes, Tycho B - V and spectral and luminosity classification compiled from the literature. Parallaxic distances may be derived for known absorbing features such as local molecular clouds and for large scale features such as sheets dividing bubbles. The stellar luminosity classes V and III offer more than 30.000 lines of sight for study, mostly for negative declinations where most classifications are available. We present some examples of this approach to derive information on the local interstellar medium. First we estimate the distance to the Southern Coalsack. Secondly, distances to the four nearby southern star forming clouds in the Chamaeleon region, the Lupus region, Corona Australis and finally the  $\rho$  Ophiuchi are estimated. We find that these clouds are at 150 (Cha), 100 pc (Lup), i.e. about 50 pc closer than previously estimated, and that a feature with  $E_{B-V} \approx 0.15$  (or  $A_V \approx 0.5$ ) appears at 50 pc in this region. A distance of 170 pc is found for CrA compared to the previous estimate of 129 pc, and finally 120 pc for  $\rho$  Oph compared to the previous 160 pc, strictly speaking the 120 pc are only measured for extinction values typical for the off core region in  $\rho$  Ophiuchus.

These distance changes are of some importance since these four regions show different stages of the star forming activity, as judged from the relative distribution of Class 0 – Class III YSOs (young stellar objects) in the  $L_{bol} - T_{bol}$  diagram. Precise calibrations of the YSOs' bolometric luminosities, applied in the definition of the bsf parameter (bsf: bright star fraction), require accurate distances of their parental clouds unless they are based on individual distances of the pre main sequence stars/protostellar sources.

Accepted by Astronomy and Astrophysics

# Ultracompact HII Regions with Extended Radio-Continuum Emission

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We have conducted a 3.6 cm radio-continuum survey with the VLA in its compact D-array to look for extended radio-continuum emission around known ultracompact HII regions. We find extended emission in 12 out of 15 fields. The extended emission ranges in size up to 5', with diameters of 60'' or 2 pc being typical. In some cases the extended component produces an order of magnitude more flux than the ultracompact component. It is possible that the extended emission is from HII regions unconnected with the ultracompact HII regions, but on the basis of the morphology of the emission we believe it is possible or even likely that the ultracompact and extended emission are directly connected in about half of the sources. The possible consequences of directly connected extended emission are profound. We may be forced to reconsider the definition of an ultracompact HII region and consider models in which dense, ultracompact ionized components are embedded in less dense, more extended regions.

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# Infrared Extinction and the Structure of the IC 5146 Dark Cloud

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We report deep near-infrared (*HK*) imaging observations of the dark cloud associated with IC 5146. With an order of magnitude greater sensitivity, we have imaged roughly half the region of the cloud originally surveyed by Lada et al. (1994). Using measurements of  $\sim 2000$  stars we have employed techniques previously developed by Lada and coworkers to construct ordered, uniformly sampled maps of the extinction through this cloud. With the improved sensitivity, we detected approximately 5 times as many heavily extinguished stars (i.e.,  $A_V \sim 20 - 50$  magnitudes) as found in the earlier survey of this same cloud area. Moreover, we were able to produce a gaussian smoothed extinction map of the cloud with an angular resolution (30 arc sec) somewhat more than a factor of two higher than achieved in the earlier study. With the increased sensitivity and angular resolution we were also able to measure the average radial column density profile orthogonal to the major axis of this filamentary cloud. Assuming cylindrical symmetry we modeled this column density gradient and determined that the corresponding volume density profile of the cloud must smoothly fall off as  $r^{-2}$ .

To investigate the structure of the cloud on size scales smaller than the effective resolution of our maps, we constructed plots of the relation between the derived mean extinction and its measured dispersion for all the pixels in a series of maps made with varying angular resolution. We find, similar to Lada et al. (1994), that the dispersion increases linearly with mean  $A_V$ , independent of the angular resolution of our maps. However, although we quantitatively reproduce the earlier results at the same angular resolution (90 arc sec), we find the interesting result that the slope of the  $\sigma_{A_V} - A_V$  relation decreases in a systematic fashion with increasing angular resolution. We construct synthetic models of the cloud density distribution and use Monte Carlo techniques to produce artificial extinction maps and investigate the origin of the  $\sigma_{A_V} - A_V$  relations. These models show that both the observed form of the  $\sigma_{A_V} - A_V$  relation and its variation with angular resolution are the natural consequences of a smooth, radially decreasing volume density gradient in a cylindrically symmetric cloud. For a volume density gradient falling off as  $r^{-2}$ , the quantitative agreements between the model predictions and data are excellent. Apparently, these relations can be understood without the need for random fluctuations in the structure of the cloud on small spatial scales.

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# On the evolutionary status of X-ray selected weak-line T Tauri star candidates in Taurus-Auriga

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We present lithium observations of 35 stars previously reported by Wichmann et al. (1996) to be possible new weak T Tauri stars (WTTS) discovered by *ROSAT* in the Taurus-Auriga star-forming region. These stars were identified on the basis of low-resolution optical spectra. We have used our higher resolution spectra for measuring the equivalent widths of the Li I 670.8 nm resonance line, and for revisiting the evolutionary status of these stars. Most (~85%) of the stars in our sample coming from *ROSAT* pointed observations are indeed confirmed to be new WTTS, but only a minority (~22%) of the stars coming from the *ROSAT* all-sky survey are confirmed as WTTS. There are two reasons why we reject some stars as WTTS. One is that seven of the stars do not have a detectable lithium line at all. The other is that we use a different definition than Wichmann et al. (1996) for classifying stars as WTTS. In particular, we identify eight stars as post T Tauri stars (PTTS) on the basis of their moderate lithium depletion. Our results confirm that the widely dispersed RASS-selected candidate WTTS tend to be older than the T Tauri stars associated with dark molecular clouds. The presence of PTTS around central Taurus suggests that the clouds may have been forming stars for more than ~10 Myr, although at a very low rate. On the basis of the PTTS identified in this work we discuss possible differences between them and the WTTS. We find that PTTS seem to have slightly lower H $\alpha$  emission equivalent width than WTTS, but the small number of known PTTS prevent us from making a strong conclusion.

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# Kinetic and Structural Evolution of Self-gravitating, Magnetized Clouds: 2.5-Dimensional Simulations of Decaying Turbulence

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The molecular component of the Galaxy is comprised of turbulent, magnetized clouds, many of which are self-gravitating and form stars. To develop an understanding of how these clouds' kinetic and structural evolution may depend on their level of turbulence, mean magnetization, and degree of self-gravity, we perform a survey of direct numerical MHD simulations in which three parameters are independently varied. Our simulations consist of solutions to the time-dependent MHD equations on a two-dimensional grid with periodic boundary conditions; an additional "half" dimension is also incorporated as dependent variables in the third Cartesian direction. Two of our survey parameters – the mean magnetization parameter  $\beta \equiv c_{sound}^2/v_{Alfven}^2$  and the Jeans number  $n_J \equiv L_{cloud}/L_{Jeans}$  – allow us to model clouds which either meet or fail conditions for magneto-Jeans stability and magnetic criticality. Our third survey parameter – the sonic Mach number  $\mathcal{M} \equiv \sigma_{velocity}/c_{sound}$  – allows us to initiate turbulence of either sub- or super- Alfvénic amplitude; we employ an isothermal equation of state throughout. We evaluate the times for each cloud model to become gravitationally bound, and measure each model's kinetic energy loss over the fluid flow crossing time. We compare the evolution of density and magnetic field structural morphology, and quantify the differences in the density contrast generated by internal stresses, for models of differing mean magnetization. We find that the values of  $\beta$  and  $n_J$ , but not the initial Mach number  $\mathcal{M}$ , determine the time for cloud gravitational binding and collapse: for mean cloud density  $n_{H_2} = 100\text{cm}^{-3}$ , unmagnetized models collapse after ~ 5Myr, magnetically supercritical models generally collapse after 5 – 10Myr (although the smallest magneto-Jeans stable clouds survive gravitational collapse until  $t \sim 15\text{Myr}$ ), while magnetically subcritical clouds remain uncollapsed over the entire simulations; these cloud collapse times scale with the mean density as  $t_g \propto n_{H_2}^{-1/2}$ . We find, contrary to some previous expectations, less than a factor of two difference between turbulent decay times for models with varying magnetic field strength; the

maximum decay time, for  $B \sim 14\mu\text{G}$  and  $n_{\text{H}_2} = 100\text{cm}^{-3}$ , is 1.4 flow crossing times  $t_{\text{cross}} = L/\sigma_{\text{velocity}}$  (or 8Myr for typical GMC parameters). In all models, we find turbulent amplification in the magnetic field strength up to at least the level  $\beta_{\text{pert}} \equiv c_{\text{sound}}^2/\delta v_{\text{Alfven}}^2 = 0.1$ , with the turbulent magnetic energy between 25-60% of the turbulent kinetic energy after one flow crossing time. We find that for non-self-gravitating stages of evolution, when clouds have  $\mathcal{M} = 5 - 10$ , the mass-averaged density contrast magnitudes  $\langle \log(\rho/\bar{\rho}) \rangle$  are in the range  $0.2 - 0.5$ , with the contrast increasing both toward low- and high-  $\beta$ . Although our conclusions about density statistics may be affected by our isothermal assumption, we note that only the more strongly-magnetized models appear consistent with estimates of clump/interclump density contrasts inferred in Galactic GMCs.

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Preprints – <http://www.astro.umd.edu/~ostriker/professional/publications.html>

## Super-strong X-ray emission from a deeply embedded young stellar object in the Serpens cloud core

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We report the ROSAT detection of strong X-ray emission from an optically invisible infrared source in the Serpens star forming region. The X-ray source can be identified with the infrared star EC 95, a deeply embedded ( $A_V \approx 34$  mag) young stellar object. The quiescent soft X-ray luminosity of this object is about  $(6 - 18) \times 10^{32}$  erg/sec, making it the most X-ray luminous young stellar object ever detected. Since this exceeds the quiescent, i.e. non-flaring, X-ray luminosity of any known coronal X-ray source by at least about one order of magnitude, our result suggests that a non-solar-like origin for the X-ray emission of EC 95 has to be considered.

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<http://www.astro.uni-wuerzburg.de/~preib/serpens.html>

## Mid-infrared imaging and spectroscopy of the southern H II region RCW 38

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We present mid-infrared images and an 8–13  $\mu\text{m}$  spectrum of the southern H II region RCW 38. We determine the dust colour temperature from both our spectrum and images at 10 and 20  $\mu\text{m}$ , and deduce the gas excitation from an image in the [SIV] fine structure line, as well as spectra of the [Ar III], [SIV] and [Ne II] fine structure lines. Our observations are consistent with a complex of sources associated with the RCW 38 IRS1 region which represent knots of material in a shell, or ridge, surrounding a cavity of about 0.1 pc in radius, which is itself created by the stellar wind of the hot young source IRS2. The dust temperature does not peak closest to IRS2, but rather along the centre of the ridge, and is remarkably uniform over the extent of our image. From photoionisation models for the observed line ratios at IRS1 we deduce a stellar effective temperature and gas density of about 43 000–48 000 K and  $10^4$   $\text{cm}^{-3}$  respectively. Whilst the star, or star cluster, IRS2 is ultimately responsible for the observed thermal and ionic emission, the relatively uniform dust temperature implies that the bulk of the dust heating in the region is provided

by resonantly trapped Lyman  $\alpha$  photons, rather than direct stellar photons. This then also implies that the dust is depleted with respect to the gas by a factor of at least 100 from its normal interstellar value. The small scale spatial variations in the continuum emission and temperature can be explained by changes in the density and/or gas-to-dust mass ratio.

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Preprint available at [www.aao.gov.au/local/www/tlb](http://www.aao.gov.au/local/www/tlb)

## Dissipation in Compressible MHD Turbulence

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We report results of a three dimensional, high resolution (up to  $512^3$ ) numerical investigation of supersonic compressible magnetohydrodynamic turbulence. We consider both forced and decaying turbulence. The model parameters are appropriate to conditions found in Galactic molecular clouds. We find that the dissipation time of turbulence is of order the flow crossing time or smaller, even in the presence of strong magnetic fields. About half the dissipation occurs in shocks. Weak magnetic fields are amplified and tangled by the turbulence, while strong fields remain well ordered.

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<http://xxx.lanl.gov/abs/astro-ph/9809357>

## Submillimetre continuum images of the NGC 2024 star-forming ridge.

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We present 450- $\mu\text{m}$  and 800- $\mu\text{m}$  images, made with the James Clerk Maxwell Telescope, of the NGC 2024 molecular ridge. The seven previously known compact cores, FIR1-7, have been detected, and FIR5 has been resolved into a compact object and an associated extended source to the east. The estimated masses of the dense cores vary between 1.6 and  $5.1 M_{\odot}$  per  $14''$  beam, assuming a dust temperature of 30 K and a dust opacity of  $\kappa_{800\mu\text{m}} = 0.002 \text{ m}^2 \text{ kg}^{-1}$ . A spectral index map made from the 450- $\mu\text{m}$  and 800- $\mu\text{m}$  images shows spatial variations, with the spectral index,  $\alpha$  ( $F_{\nu} \propto \nu^{\alpha}$ ), being systematically lower towards the dense cores. We interpret this as evidence for a lower value of the frequency dependence of the dust opacity,  $\beta$ , towards the denser cores relative to the surrounding molecular material. This may indicate grain growth is occurring in the cores, prior to planetesimal formation. By comparing the high resolution 450- $\mu\text{m}$  image with interferometer maps of the integrated CS(2-1) emission, the previously reported discrepancy between dust continuum emission and molecular line emission has been found to be very localised. Depletion and temperature variations are discussed as possible explanations.

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## The Eagle Nebula's fingers - pointers to the earliest stages of star formation ?

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Molecular line, millimetre/submillimetre continuum, and mid-IR observations are reported of the opaque fingers which cross the Eagle Nebula. The fingers are surprisingly warm when viewed in the CO  $J=3-2$  lines, with kinetic temperatures approaching 60 K, although the lines are relatively narrow. Most of the mass in the fingers is concentrated in cores which lie at the tips of the fingers, and contain from  $\sim 10$  to  $60 M_{\odot}$ , representing 55 – 80 % of the mass of the individual fingers. The integrated mass contained in the three fingers and the nearby extended material is  $\sim 200 M_{\odot}$ . The velocity fields of the gas are complex and the material is very clumpy. The best evidence for coherent velocity structure is seen running along the central finger, which has a velocity gradient  $\sim 1.7 \text{ km s}^{-1} \text{ pc}^{-1}$ . The fingers contain several embedded submm continuum cores, with the most intense located at the tips of the fingers. The continuum spectra of these cores shows that they are much cooler,  $T_{dust} \sim 20 \text{ K}$ , than  $T_{gas} \sim 60 \text{ K}$  of their respective fingers. A simple thermal and chemical model of a finger was developed to study the physical environment, which takes into account the external UV illumination ( $\sim 1700 G_{\odot}$ ), and the chemical and thermal structure of a finger.

The model predictions are consistent with all of the available observations. The fingers appear to have been formed after primordial dense clumps in the original cloud were irradiated by the light of its OB stars. These clumps then shielded material lying behind from the photoevaporative dispersal of the cloud, and facilitated the formation of the finger structures. The cores in the tips of the fingers appear to be at a very early stage of *pre-protostellar* development: there are no embedded infrared sources or molecular outflows present. The pressure inside the cores is just less than that of the surrounding gas, allowing them to be compressed by the external pressure. The cores are probably just starting the final stages of collapse, which will lead to the formation of a condensed, warm object. It is well known that such characteristics are expected from the earliest stages of objects popularly known as ‘protostars’. *The cores in the tips of the Eagle Nebula’s fingers have characteristics similar to those expected to occur in the earliest stages of protostellar formation.*

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<http://white.ph.qmw.ac.uk/eagle/eagle.html>

## The Synchrotron Jet from the H<sub>2</sub>O Maser Source in W3(OH)

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We report results of sensitive Very Large Array observations of the 8.4 GHz continuum emission associated with the TW object, a luminous young star located at the center of expansion of the H<sub>2</sub>O masers in the W3(OH) region. The source has a radio spectral index of  $-0.6$  and exhibits a sinuous double-sided morphology; these are characteristics of a synchrotron jet. No significant changes are seen in the jet morphology in observations separated by 510 days. The inhomogeneous synchrotron model proposed by Reid et al. (1995), based on the spectrum and size variation with observing frequency, correctly predicts the flux-density profile of the radio emission.

Secondary radio continuum features located at the extrema of the H<sub>2</sub>O maser distribution may mark the location of strong shocks and deeply embedded Herbig-Haro objects, or additional young stellar objects in the W3(OH) cluster. Several more compact sources are identified in the region, some of which are highly variable. These may be low-mass pre-main-sequence stars with magnetic activity.

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## *New Jobs*

### **Post Doctoral position at Stockholm Observatory**

The **IR-group** at Stockholm Observatory (Dept. of Astronomy & Astrophysics, Stockholm University, Sweden) has currently the opportunity to offer **2 postdoc** fellowships. Successful applicants are expected to have documented their experience in the field of **Star Formation** and related topics such as the Physics and/or the Chemistry of the Interstellar Medium and should be familiar with the analysis and interpretation of ISO data. Preferred commencement is by January 1, 1999 (or according to agreement) and the duration will be for one year each, with the possibility of renewal for another year. Applications should be forwarded to either of:

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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, where you can access it via the ESO Portal (<http://http.hq.eso.org/eso-homepage.html>). You can also access it through the University of Massachusetts Astronomy World Wide Web server, the URL for its home page is <http://www-astro.phast.umass.edu/>

## 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.