THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

No. 30 — 12 February 1995 Editor: Bo Reipurth (reipurth@eso.org)

Abstracts of recently accepted papers

Methanol enhancement in young bipolar outflows

R. Bachiller[1], S. Liechti[1], C.M. Walmsley[2], and F. Colomer[1]

[1] Centro Astronómico de Yebes, Apartado 148, E-19080 Guadalajara, Spain
[2] Physikalisches Institut, Universität zu Köln, Zulpicherstr. 77, D-50937 Köln, Germany

E-mail contact: bachiller@cay.es

We report observations of the 2_k–1_k, 3_k–2_k, and 5_k–4_k thermal lines of CH_3OH toward young bipolar outflows. Strong emission ($\gtrsim$ 6 K, in the case of L 1157) is observed toward the shocked molecular regions associated with the lobes of some outflows, whereas the emission from the cold quiescent material in the surrounding molecular core is rather weak ($\lesssim$ 1 K). We have derived the methanol abundance by combining the CH_3OH data with new $C^{18}O$ observations. It results that methanol is enhanced by large factors toward the shocked regions ($\sim$ 400 toward the blue-shifted lobe of L 1157). Although the shocked gas is known to be heated to about 100 K, the CH_3OH rotation temperatures have moderate values: in L 1157 $T_{\rm rot}$ increases from 8 K in the ambient gas to 12 K in the shocked region. Radiative transfer calculations, carried out to simulate the CH_3OH excitation in different physical circumstances, confirm that in the range of physical conditions discussed here the methanol molecules are very subthermally excited, and $T_{\rm rot}$ is not a good measure of the kinetic temperature ($T_{\rm rot} << T_{\rm K}$). The observed methanol abundance enhancements are likely caused by processes of desorption of grain mantles in shocks.

Accepted by Astron. Astrophys. (Letters)

Rotation, winds and active phenomena in Herbig Ae/Be stars

T. Böhm[1] and C. Catala[2]

[1] Département d'Astrophysique Extragalactique et de Cosmologie et Unité de Recherche associée au CNRS 173 et à l'Université Paris 7, Observatoire de Paris, Section de Meudon, 92195 Meudon Principal Cedex, France and Landessternwarte Königstuhl, 69117 Heidelberg, Germany
[2] Département de Recherche Spatiale et Unité de Recherche associée au CNRS 264, Observatoire de Paris, Section de Meudon, 92195 Meudon Principal Cedex, France

E-mail contact: tboehm @ eso.org

This paper presents new statistical studies based on a sample of 29 Herbig Ae/Be stars spectra, mostly observed with the MUSICOS echelle spectrograph at the Telescope Bernard Lyot at the Pic du Midi Observatory. The high S/N spectra cover the visible domain with a resolution of $R = 38000$. Two major problems are investigated in detail.

After a precise redetermination of the $v \sin i$ of our objects, we study in detail the angular momentum evolution of these PMS stars of intermediate mass, by comparing their $v \sin i$ distribution with that of A- and B-type stars in young open clusters. Our data show that, if the stars rotate as solid bodies, low mass Herbig stars ($M \leq 2.6\,M_\odot$) lose a large fraction of their angular momentum during their PMS evolution, which could be accounted for by stellar winds with mass loss rates of the order of $10^{-8}\,M_\odot\,{\rm yr}^{-1}$; intermediate mass Herbig stars (between 2.6 and $4\,M_\odot$) do not lose a significant fraction of their angular momentum; finally, higher mass Herbig stars ($M \geq 4\,M_\odot$) seem to gain large amounts of angular momentum. Alternatively, the observed vsini distributions for Herbig stars and in young open clusters are roughly consistent with a conservation of total angular momentum at all masses if the internal rotation

rate varies across the star, e.g. if $\Omega(r)$ goes as r^{-2} (constant specific angular momentum).

As a second major point, we analyze activity and wind tracers like Ca II IR triplet, He I 5876 Å and Hα lines, by estimating the excess of the observed line luminosities and surface fluxes with respect to standard photospheric models. We find that the ratio of the excess-line luminosities to the total stellar luminosities presents a maximum at spectral type A0, while the excess-line fluxes increase monotonically with effective temperature. We show that this behavior tends to contradict the suggestion that the origin of activity and winds in these stars may be linked to a boundary layer between the star and an accretion disk. No correlation was found between the various tracers and the projected rotation velocity.

Accepted by Astron. Astrophys.

The Line Width - Size Relation in Massive Cloud Cores

P. Caselli and P. C. Myers

Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: pcaselli@cfa

We report ^{13}CO and C^{18}O line observations and maps in Orion A (L1641) and B (L1630). Together with already published observations, these data are used to study the line width - map size relation in massive star forming regions. The nonthermal component of the linewidth (Δv_{NT}) in Orion cores follows the trend $\Delta v_{NT} \sim R^q$ with q=0.21±0.03, significantly different from q=0.53±0.07 found in low mass cores. These relations are analysed in the context of an equilibrium model of a spherically symmetric dense core which incorporates both thermal and nonthermal (TNT) motions. The internal consistency of the TNT model and Δv_{NT}-R data is shown. We present general formulas for the TNT model and apply them to the observational data. Differences in the slope and in the intercept of the Log Δv_{NT} - Log R relation between massive and low mass cores imply significant differences in density structure, pressure profile, mass infall rate, and probably in the masses of stars which form. In particular, massive cores are denser and have steeper density profiles than low mass cores. Visual extinction values predicted by the TNT model for low mass and massive cores (3.3 and 16 mag, respectively) are in good agreement with available observational estimates for similar objects. The higher density and pressure in massive cores lead to values for the infall time for 1 $M_\odot$ of $\sim 7\times10^4$ yr, about six times shorter than in low mass cores. Massive dense cores associated with embedded young stellar objects have physical properties almost identical to neighboring massive starless cores. Thus, the formation of a star or a small group of stars does not significantly affect the initial physical conditions of the associated molecular cloud core. On the other hand, line widths of ammonia cores become narrower as the distance from embedded young stellar clusters increases. In particular, the massive core farthest away from embedded clusters is mostly thermal and its kinetic temperature is $\sim$ 10 K, about two times lower than the typical kinetic temperature of massive cores.

Accepted by The Astrophysical Journal

The Molecular Gas Content of the Keyhole Nebula.

P. Cox[1,2], P.G. Mezger[2], A. Sievers[3], F. Najarro[4], L. Bronfman[5], E. Kreysa[2], G. Haslam[5]

[1] Observatoire de Marseille, 2 pl. Leverrier, F–13248 Marseille cedex 04, France
[2] Max–Planck–Institut für Radioastronomie, Postfach 2024, D-53121 Bonn, Germany
[3] Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile

E-mail contact: p427cox@mpifr.bonn-mpg.de

We report the detection of molecular gas emission associated with the Keyhole nebula located near Eta Carinae. A detailed map of ^{12}CO(2-1) is presented covering a field of 8 x 7 arcmin^2. In a few directions other molecular lines were observed. The distribution of the molecular gas is very inhomogeneous, breaking up into at least nine clumps most of them well separated both in space and in velocity. Their typical size is a few tenths of a parsec with linewidths in the range $2 - 4\,\mathrm{km\,s^{-1}}$ and masses of $\sim 10\,M_\odot$. We present evidence suggesting that the dense clumps are unbound and supported by the external pressure of the surrounding ionized gas. The dynamics of the molecular gas are highly perturbed: the clumps separation, projected in the plane of the sky, is of less than a parsec with velocity differences of up to $20\,\mathrm{km\,s^{-1}}$. Such a velocity dispersion, which is comparable with that measured in the ionized gas, is likely to be a result of the interaction between the strong stellar winds of Eta Carinae and the surrounding gas.

Accepted by Astron. Astrophys.

Millimeter emission of Eta Carinae and its surroundings.

P. Cox[1,2], L. Bronfman[3]

[1] Observatoire de Marseille, 2 pl. Leverrier, F–13248 Marseille cedex 04, France
[2] Max–Planck–Institut für Radioastronomie, Postfach 2024, D-53121 Bonn, Germany
[3] Institut de Radio Astronomie Millimétrique, Ave. Pastora Divina, Granada, Spain
[4] Institut für Astronomie und Astrophysik der Universität, Scheinerstrasse 1, D–97074 München, Germany
[5] Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile

E-mail contact: p427cox@mpifr.bonn-mpg.de

Using the SEST telescope we have mapped the λ 1.3-mm and 2.9-mm continuum emission around Eta Carinae (η Car), the peculiar star belonging to the open cluster Trumpler 16 in the Carina Nebula. The maps are dominated by a central source whose position coincides with η Car. Extended millimeter continuum emission is detected both at λ 1.3 and 2.9-mm. This emission traces the optically thin free-free emission from the gas ionized by the nearby massive luminous stars of Trumpler 16.

In 1992, the flux densities of η Car were 15.8$\pm$1.9 Jy at λ1.3-mm and 4.9$\pm$0.7Jy at 3-mm. From an analysis of the spectrum from the near-infrared to the decimeter radio range, we show that the millimeter emission of η Car is dominated by thermal emission from the ionized stellar wind. The infrared emission is dominated by dust radiation with temperatures ranging from 200 to 400 K. The total luminosity is $L_{IR} = 5\ 10^6\ L_\odot$. Based on the millimeter flux densities measured in 1992, we derive a mass-loss rate of $\sim 2.4\,10^{-3}\,M_\odot yr^{-1}$. Measurements obtained during the time interval from 1991 to 1994 indicate strong flux density variations at both millimeter wavelengths. We suggest that these variations are related to episodic shell ejections leading to variations in the degree of ionization in the wind of η Car.

Accepted by Astron. Astrophys.

Millimeter recombination lines towards Eta Carinae

P. Cox[1,2], J. Martin-Pintado[3], R. Bachiller[3], L. Bronfman[4], J. Cernicharo[3], L.-Å. Nyman[5], P. R. Roelfsema[6]

[1] Observatoire de Marseille, 2 pl. Leverrier, F–13248 Marseille cedex 04, France
[2] Max–Planck–Institut für Radioastronomie, Postfach 2024, D-53121 Bonn, Germany
[3] Centro Astronomico de Yebes, Apartado 148, E-19080 Guadalajara, Spain
[4] Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile
[5] European Southern Observatory, Casilla 19001, Santiago 19, Chile
[6] SRON, Postbus 800 AV, Groningen, The Netherlands

E-mail contact: p427cox@mpifr.bonn-mpg.de

We report the detection of the millimeter recombination lines H40α, H30α, H29α, H50β and H37β towards Eta Carinae (η Car). All the recombination lines show a similar line profile. A strong narrow component is seen at a velocity of $V_{lsr} \sim -50$ kms^{-1}, significantly blue–shifted with respect to the systemic velocity of η Car (-16 kms^{-1}). Underlying this main component a very broad emission is also detected in the α lines, extending from ~ -200 to ~ 100 kms^{-1}. The profiles are markedly asymmetrical in the sense of enhanced blue-shifted emission both in the narrow and the broad features. We argue that most of the red-shifted emission is absorbed by the optically thick, strong radio continuum of the ionized stellar wind of η Car and that the millimeter recombination lines are affected by maser emission. This is supported by simple model calculations for the radiation transfer of the line and continuum emission in η Car.

Accepted by Astron. Astrophys. Letters

Distinction of parallel outflows in L 1448 through H_2 excitation

Christopher J. Davis and Michael D. Smith

Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

E-mail contact: davis@mpia-hd.mpg.de, smith@mpia-hd.mpg.de

High-resolution infrared maps of the emission from warm molecular gas in the L 1448 outflow region are presented. Comparison of images from H_2 lines produced from the first and second vibrational levels demonstrates the presence of two distinct parallel outflows. The main outflow (from the L 1448-mm source) is of high excitation and shows remarkably little spatial variation in the 1-0 S(1)/2-1 S(1) intensity ratio, which remains near 10 across the whole ridge. Two explanations are offered: (a) the ridge consists of numerous fine-scale C-type bow shocks and/or (b) supersonic turbulence in a shear layer generates a C-type self-similar shock velocity distribution. The second outflow (from the IRS 3 source) is of low excitation, suggesting a combination of lower density and temperature.

Accepted by Astrophys. J. Letters

Ultracompact HII regions: Are their lifetimes extended by dense, warm environments?

C. G. De Pree[1,2], L. F. Rodríguez[1,3] and W. M. Goss[1]

[1] National Radio Astronomy Observatory, P.O. Box O, Socorro, NM 87801, USA
[2] Department of Physics and Astronomy, University of North Carolina at Chapel Hill, USA
[3] Instituto de Astronomia, Universidad Nacional Autonoma de Mexico, Mexico

E-mail contact: cdepree@nrao.edu

Ultracompact HII regions (UCHIIs) are defined as regions of ionized gas with diameters smaller than ∼0.1 pc (Wood & Churchwell 1989a). HII regions are expected to expand at velocities on the order of the sound speed (10 km s^{-1}) until reaching equilibrium at dimensions of a few pc. In regions with density of n_o ∼10^5 cm^{-3}, HII regions should remain ultracompact for ∼3000 years and only a few dozen should exist in the Galaxy. However, observations suggest that many more UCHIIs exist and that lifetimes should be one to two orders of magnitude larger. Several models have been proposed to explain this "lifetime paradox"; all have shortcomings. The paradox could be resolved if the molecular gas in which an O star forms is denser and warmer than previously believed, resulting in an initial Strömgren sphere much smaller than originally estimated. This suggestion finds support in recent observations, which show that in dense molecular cloud cores densities of 10^7 cm^{-3} and temperatures of 100 K are not atypical. We compare the expected UCHII radii (using the higher temperatures and densities) with the observed radii of a sample of UCHII regions and find significant agreement between the two.

Accepted by Revista Mexicana de Astronomía y Astrofísica

Rotation and outflow in compact HII regions: VLA observations of the molecular and ionized gas in NGC 6334A and F

C. G. De Pree[1,2], L. F. Rodríguez[1,3], H. R. Dickel[4] and W. M. Goss[1]

[1] National Radio Astronomy Observatory, P.O. Box O, Socorro, NM 87801, USA
[2] Department of Physics and Astronomy, University of North Carolina at Chapel Hill, USA
[3] Instituto de Astronomia, Universidad Nacional Autonoma de Mexico, Mexico
[4] Astronomy Department, University of Illinois, USA

E-mail contact: cdepree@nrao.edu

Two compact components of the NGC 6334 star forming region have been imaged in molecular and ionized gas at high spatial and spectral resolution with the Very Large Array. The H II region NGC 6334A has been imaged in the radio continuum at 6 cm, 3.6 cm, and 2 cm, and in the recombination lines H76α (2 cm) and H92α (3.6 cm). NGC 6334F has been imaged at 6 cm and 2 cm in the radio continuum, and in the H76α recombination line. Both components have been imaged in the $J_{KK}=1_{10} \rightarrow 1_{11}$ (6 cm) and $J_{KK}=2_{11} \rightarrow 2_{12}$ (2 cm) lines in H_2CO absorption. Components A and F are separated by ∼11 arcmin (5.4 pc) along a star forming ridge. In component A, high resolution (∼3 arcsec)

continuum observations confirm the presence of a ∼15 arcsec diameter shell. Spectral observations of the ionized gas in component A at both frequencies show velocity gradients that are consistent with rotation in the ionized gas. In addition, a bipolar outflow is observed along the perpendicular axis into the 'lobes' to the north and south of the compact core. In component F, there is a velocity gradient in the ionized gas that is along the same axis as the bipolar CO outflow observed by Bachiller & Cernicharo (1990). The H_2CO absorption lines toward both components suggest outflow in the molecular gas.

Accepted by The Astrophysical Journal

Shock diagnostics in Herbig-Haro 7: Evidence for H_2 fluorescence

A. Fernandes[1,2], P. Brand[1],

[1] Institute for Astronomy, Blackford Hill, Edinburgh EH9 3HJ, Scotland
[2] Centro de Astrofísica, Universidade do Porto, Rua do Campo Alegre, 823, 4150 Porto, Portugal

E-mail contact: almfern@ciup1.ncc.up.pt, P.Brand@roe.ac.uk

Near-infrared spectra have been obtained between 2μm and 2.5μm at six positions in Herbig-Haro object 7 which show emission lines of molecular hydrogen arising from upper energy levels ranging from 6000 K to 25000 K. Planar J- and C-type shock models fail to predict the relatively large columns of warm gas measured in the higher vibrational levels (v > 2) of H_2. We suggest that the excess emission observed in these high-excitation lines arises from H_2 fluorescence produced by Lyα pumping of the lower density ($\sim 10^3$–10^4) pre-shocked gas, while the bulk of the H_2 emission is excited in the hotter and denser ($\sim 10^5$–10^6) post-shocked layers behind a bow C-shock. By comparing the observed line ratios with the H_2 emission from a composite *"Bow C-shock + Fluorescence"* model, we derive that the shock-induced UV radiation field is about 10^2–10^3 times larger than the average interstellar field, and that the ortho-to-para ratio of the fluorescent H_2 population is 1.8. The best fit parameters for the bow yield a shock velocity, $V_s = 140$ km s^{-1} with the axis of symmetry positioned at $\theta = 40°$ to the line of sight. This configuration suggests that the bow's dissociative cap (bow apex) is producing a Far-UV radiation field of the order 0.16–1.6 ergs s^{-1} cm^{-2}.

Accepted by MNRAS

The Parker-Shearing instability in azimuthaly magnetized disc

T. Foglizzo[1,2] and M. Tagger[1]

[1] CEA/DSM/DAPNIA, Service d'Astrophysique, CE-Saclay, 91191 Gif-sur-Yvette Cedex, France
[2] Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, Postfach 15 23, 85740 Garching, Germany

E-mail contact: foglizzo@mpa-garching.mpg.de

We describe the effects of both magnetic buoyancy and differential rotation on a disc of isothermal gas embedded in a purely azimuthal magnetic field, in order to study the evolution and interplay of Parker and shearing instabilities. We perform a linear analysis of the evolution of perturbations in the shearing sheet model. Both instabilities occur on the slow MHD branch of the dispersion relation, and can affect the same waves. We put a stress on the natural polarization properties of the slow MHD waves to get a better understanding of the physics involved. The mechanism of the shearing instability is described in details.
Differential rotation can transiently stabilize slow MHD waves with a vertical wavelength longer than the scale height of the disc, against the Parker instability. Waves with a vertical wavelength shorter than the scale height of the disc are subject to both the Parker and the transient shearing instabilities. They occur in different ranges of radial wavenumbers, i.e. at different times in the shearing evolution; these ranges can overlap or, on the contrary, be separated by a phase of wave-like oscillations, depending on the strength of differential rotation.
These analytical results, obtained in a WKB approximation, are found to be in excellent agreement with numerical solutions of the full set of linearized equations. Our results can be applied to both galactic and accretion discs.

Accepted by Astronomy and Astrophysics

Infrared response of H_2 to X-rays

Roland Gredel[1] **and Alex Dalgarno**[2]

[1] European Southern Observatory, Casilla 19001, Santiago 19, Chile
[2] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

E-mail contact: rgredel@eso.org

The rates of population of the rovibrational levels of H_2 by the impact of energetic photoelectrons produced by the absorption of X-rays are calculated. Population occurs by excitation of electronically excited states of H_2 followed by cascading and by direct impact excitation of the lowest vibrational level. The resulting infrared spectra are obtained. The emission from high vibrational levels is similar to that from ultraviolet pumping. Emission from the v=1 and 2 vibrational levels in a gas of low fractional ionization is dominated by direct electron impact excitation. The intensity ratio of the $S(1)(2,1)$ and $S(1)(1,0)$ lines is 0.06 in a gas of low fractional ionization and 0.54 in a gas of high fractional ionization.

Accepted by Astrophys. J.

Detection of a Circumstellar Gas around DM Tau; A Protoplanetary Disk around a Single Star?

Toshihiro Handa[1], **Shoken Miyama**[2], **Takuya Yamashita**[2], **Toshihiro Omodaka**[3], **Yoshimi Kitamura**[4], **Masahiko Hayashi**[5], **Toshikazu Onshi**[6], **Ronald L. Snell**[7,8], **Stephen Strom**[7], **Karen Strom**[7],, **M. F. Skrutskie**[7], **S. Edwards**[9], **Nagayoshi Ohashi**[10], **Kazuyoshi Sunada**[10], **Masao Saito**[10], **Yasuo Fukui**[6], **Akira Mizuno**[6], **Jun-ichi Watanabe**[2], **Hirokazu Kataza**[1]

[1] Institute of Astronomy, University of Tokyo, 2-21-1 Osawa, Mitaka, Tokyo 181, Japan
[2] National Astronomical Observatory, 2-21-1 Osawa, Mitaka, Tokyo 181, Japan
[3] College of Liberal Arts, Kagoshima University, 1-21-30 Koorimoto, Kagoshima 890, Japan
[4] Department of Liberal Arts, School of Allied Medical Sciences, Kagoshima University, 8-35-1 Sakuragaoka, Kagoshima 890, Japan
[5] Department of Astronomy, University of Tokyo, Yayoi, Bunkyo, Tokyo 113, Japan
[6] Department of Astrophysics, Nagoya University, Chikusa, Nagoya 464-01, Japan
[7] Physics and Astronomy Department, University of Massachusetts, Amherst, MA 01003, USA
[8] Five College Radio Astronomy Observatory, University of Massachusetts, Amherst, MA 01003, USA
[9] Astronomy Department, Smith College, Northampton, MA 01063, USA
[10] Nobeyama Radio Observatory, Minamimaki, Minamisaku, Nagano 384-13, Japan.

Sensitive molecular line observations carried out with the Nobeyama 45-m telescope have resulted in the detection of the ^{12}CO (J=1-0) and ^{13}CO (J=1-0) emission centered on the young, classical T Tauri star, DM Tau. The derived peak antenna temperatures are 0.3 K in ^{12}CO and 0.1 K in ^{13}CO. No C^{18}O emission was detected at an upper limit (3 sigma) of 45 mK. The emission feature has a line width of 1.7 km/s and is centered at v_{LSR} = 5.9 km/s, which coincides well with the reported radial velocity for DM Tau (5.9 ± 2.1 km/s). The ^{13}CO profile shows symmetric double peak suggesting a Keplerian rotating disk. These observations suggest that the molecular gas is associated with and is most probably gravitationally bound to DM Tau. The derived radius of the gaseous disk is about 1000 AU using an optically thick disk model and a Keplerian rotating disk model. The gaseous mass is between 7x10^{-4} and 1x10-3 $M_\odot$ from the ^{13}CO intensity and the upper limit of C^{18}O intensity. Our results suggest that molecular gas is depleted from the standard gas-to-dust mass ratio or that mass distribution in the disk is steeper than the standard law, $r^{-1.5}$, although our observations cannot detect emission from an optically thick gaseous component inward of r < 100 AU, if the emission comes from a Keplerian rotating disk.

Accepted by Astrophys. J.

The young Herbig-Ae/Be star LkHα 349

F.V. Hessman[1,2], S.V.W. Beckwith[2], R. Bender[3], J. Eislöffel[4], W. Götz[5], and E. Guenther[6]

[1]Universitäts-Sternwarte, Geismarlandstr. 11, D–37083 Göttingen, Germany
[2]Max-Planck-Institut für Astronomie, Königstuhl 17, D–69117 Heidelberg, Germany
[3]Universitäts-Sternwarte, Scheinerstr. 1, D-8000 München, Germany
[4]Observatoire de Grenoble, B.P. 53X, F–38041 Grenoble Cedex, France
[5]Sternwartestr. 23a, D–96515 Sonneberg, Germany
[6]Dept. of Physics, Queen Mary & Westfield College, Mile End Road, London E1 4NS, U.K.

E-mail contact: hessman@uni-sw.gwdg.de

We present observations of the unique pre-main sequence object LkHα 349, the central star of the cometary nebula IC 1396A. The optical spectrum is dominated by strong P Cygni Balmer and Na D lines and the broad and shallow absorption lines of a rapidly rotating F8 star. The blue-shifted P Cygni absorption wings extend to 500-700 km/s and are indicative of a very strong stellar wind. The spectral energy distribution from the optical through the far-infrared is that of a single F star with moderate extinction, a radius of 8.4 $R_\odot$ (L=84 $L_\odot$), and no obvious contribution from a circumstellar disk. The deconvolved absorption line broadening function shows a $v \sin i$ of $193 \pm 12\, km/s$, suggesting that LkHα 349 is rotating at near break-up. LkHα 349 sits in the middle of a substantial circumstellar "hole" which it may have blown out of IC 1396A. All of these characteristics can be understood if LkHα 349 is a pre-main sequence star of intermediate mass ($\geq 3\, M_\odot$) on its way towards becoming a Herbig Be star. The wind must be the star's response to the problem of rotating so quickly while rapidly contracting down to the main sequence. Due to the very short contraction times expected for intermediate-mass stars, LkHα 349 gives us a rare glimpse of a young star during a very short but important period in its pre-main sequence life.

Accepted by A&A.

Imaging the small-scale gas around T Tauri stars

D. W. Koerner[1] and A. I. Sargent[2]

[1] 169-506 Jet Propulsion Laboratory, 4800 Oak Grove Drive., Pasadena, CA 91009, USA
[2] 105-24, California Institute of Technology, Pasadena, CA 91125, USA

E-mail contact: davidk@coma.jpl.nasa.gov

We have detected circumstellar molecular gas around a small sample of T Tauri stars through aperture synthesis imaging of CO(2→1) emission at ∼ 2-3″ resolution. RY Tauri, DL Tauri, DO Tauri, and AS 209 show resolved and elongated gaseous emission. For RY Tau, the deconvolved, half-maximum radius along the direction of elongation, PA∼48°, is 110 AU. Corresponding radii and orientations for the other sources are: DL Tau – 250 AU at PA∼84°; DO Tau – 350 AU at PA∼160°; AS 209 – 290 AU at PA∼138°. RY Tau, DL Tau, and AS 209 show velocity gradients parallel to the elongation, suggesting that the circumstellar material is rotating. RY Tau and AS 209 also exhibit double-peaked spectra characteristic of a rotating disk. Line emission from DO Tau is dominated by high-velocity blue-shifted gas which complicates the interpretation. Nevertheless, there is in each case sufficient evidence to speculate that the circumstellar emission may arise from a protoplanetary disk similar to that from which our solar system formed.

Accepted by Astron. J.

Near Infrared Images of IC 348 and the Luminosity Function of Young Embedded Clusters

Elizabeth A. Lada[1] and Charles J. Lada[2]

[1]Department of Astronomy, University of Maryland, College Park, MD 20742, USA
[2]Harvard-Smithsonian Center for Astrophysics, 60 Garden St. Cambridge, MA 02138, USA

E-mail contact: lada@astro.umd.edu, clada@cfa.harvard.edu

We present the results of a sensitive near-infrared (JHK) imaging survey of the young cluster IC 348 and a nearby control field. From comparison of the cluster and control field observations we estimate that 380 sources, the majority

of the stars observed in the cluster field, are members of the cluster. The spatial density of these stars is found to be significantly larger than that typical of classical open clusters but comparable to that which characterizes young embedded clusters such as NGC 2024 and the Trapezium. Overall, we find the surface density distribution of stars in IC 348 to be centrally concentrated and to decrease inversely with distance from the inner (r $\approx$ 0.1 pc) to the outer (r $\approx$ 1.0 pc) regions of the cluster. In detail the stellar surface density distribution of this cluster exhibits significant structure. Roughly half the stars are contained within a central sub-cluster with a radius of 0.5 pc. Outside this half-mass radius, we identify eight small sub-clusters which contain 10-20 stars and have radii 0.1-0.2 pc in extent.

We construct the K luminosity function (KLF) for IC 348 and find it to increase with magnitude in a non-linear, power-law fashion in the range $8 \leq m_K \leq 11$ magnitudes. The measured slope (0.40) of the power-law portion of the IC 348 KLF is very similar to the slopes (0.37-0.38) determined for the KLFs of four young embedded clusters in Orion. The IC 348 KLF departs from a power-law shape at $m_K > 11$ magnitudes, and appears to decrease at magnitudes ($m_K \approx 14$) near the completeness limit of the survey.

We construct evolutionary models for the near-infrared luminosity functions of young ($\tau_{cl} \leq 10^7$yrs.) star clusters containing pre-main sequence stars. We find that the KLFs of very young synthetic clusters evolve in a systematic and predictable manner as the clusters age. For a fixed IMF, the shape of a cluster KLF depends primarily on the duration of the star formation (τ_{sf}) and the age (τ_{cl}) of the cluster. In general we find that the luminosity functions of young clusters broaden with age. For coeval models (i.e., $\tau_{sf} << \tau_{cl}$) the slopes of the power-law portion of the KLFs exhibit significant variation with time, while models with continuous star formation (i.e., $\tau_{sf} \approx \tau_{cl}$) maintain more or less constant slopes as they age. The observed similarity between the KLF slopes of numerous embedded clusters and those of the models suggests that uniform, continuous star formation may be characteristic of the star formation histories of many embedded clusters. From comparison of our models with our observations of IC 348 we conclude that star formation in IC 348 has been a continuous process over the last 5-7 x 10^6 years and that the overall rate of star formation and the rate of star formation as a function of mass has been constant over the cluster lifetime. From a comparative analysis of published observations of the Trapezium cluster with our models and observations of IC 348, we find that the underlying mass function of both clusters is similar to the IMF for field stars down to the hydrogen burning limit with little evidence for a significant population of single, lower mass objects (brown dwarfs). In addition we also find that despite the similarities in their mass functions, stellar densities and sizes, IC 348 and the Trapezium have been characterized by significantly different rates of star formation over their lifetimes. The rate of star formation in the younger Trapezium cluster has been a factor of 20 greater than that in IC 348.

Finally, analysis of the JHK colors of the stars in IC 348 reveals that $\sim$ 20% of the cluster sources are infrared excess sources. The size of the population of infrared excess sources coupled with the age of the cluster suggests a lifetime of 2-3 x 10^6 years for the (proto-planetary) disk phase of early stellar evolution, consistent with previous estimates.

Accepted by The Astronomical Journal, to appear in April 1995

PAH emission from Herbig Ae/Be and T Tauri stars

A. Natta [1] **and E. Krügel** [2]

[1] Osservatorio Astrofisico di Arcetri, Largo Enrico Fermi 5, I–50125 Firenze, Italy
[2] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D–53121 Bonn, Germany

We present models for the mid infrared emission of Herbig Ae/Be and T Tau stars. Special attention is given to the contribution from grains with temperature fluctuations consisting of PAHs, with their well known IR features, and very small graphite particles. We discuss in detail model calculated spectra between 3 and 15μm and the predicted brightness distribution at different wavelengths.

The models are meant as a guide to observers. They have been obtained over a wide range of parameters for the star and its environment so that observed objects are bracketed by the set of models. In particular, we varied in the calculations the luminosity of the star and the optical depth and density distribution of the dust. We checked that our predicted emission, especially the strength of the 3.3 and 11.3μm PAH features, is in accord with present data. Our theoretical results on the features, their strength and intensity ratios, and the variation of the emission over the source may be used to derive some of the key parameters of pre-main–sequence stars.

Furthermore, we calculate the percentage of stellar light that is absorbed by grains with temperature fluctuations as a function of stellar type and for various PAH cross sections; values vary between 10 and 35%. We also study

the influence of presently poorly determined PAH properties, like their size and optical or UV cross section, on the spectrum. We argue that PAH features are not observed in T Tau stars, although the models predict them, because they may be swamped by the continuum emission of the star or disk.

Accepted by Astron. & Astrophys.

The Large Scale Structure, Kinematics and Evolution of IC1396

Nimesh A. Patel[1,2], **Paul F. Goldsmith**[3], **Ronald L. Snell**[1], **Thomas Hezel**[1] and **Taoling Xie**[4]

[1] FCRAO, University of Massachusetts, Amherst, MA 01003, USA
[2] Center for Astrophysics, 60 Garden St. MS-42, Cambridge, MA 02138, USA
[3] National Astronomy & Ionosphere Center, Cornell University, Space Sciences Bldg., Ithaca, NY 14853-6801, USA
[4] Jet Propulsion Laboratory,MS 169-506, California Institute of Technology, Pasadena, CA 91109, USA

We have mapped the diffuse HII region IC1396 in the J=1-0 transition of CO and ^{13}CO, using the FCRAO 14 meter telescope with the QUARRY focal plane array receiver. The prominent bright rimmed globules are found to lie on a ring of radius 12 pc, expanding with a velocity of 5 km s^{-1}. The CO map extends well beyond this ring but CO emission is found to be very weak outside the ring. The dynamical age of the system of globules, as suggested by its expansion, is 2$\sim$ 3 Myrs, consistent with the age estimates of the exciting O6 star, HD206267. Nyquist-sampled CO and ^{13}CO maps of selected globules show evidence of interaction with the UV radiation from HD206267. 24 IRAS point sources in the mapped field satisfy criteria of young stellar objects; 10 of these sources are directly associated with IC1396 globules, suggesting that star formation is occurring within them. In a mass-UV flux parameter space, globules with the IRAS sources are distinct from the globules without IRAS sources, being relatively more massive. The ring of globules itself appears to be embedded in a larger elliptical structure $\sim 9^o$ (120 pc) in size, which appears in the IRAS maps of 60 and 100 micron emission. We suggest that star formation in the Cepheus region has proceeded by sequential triggering, and the stars forming in the globules of IC1396 represent the youngest generation of stars in this region.

Accepted by ApJ

Ammonia Emission from Bow Shocks in the L1157 Outflow

Mario Tafalla[1], **Rafael Bachiller**[2]

[1] Harvard-Smithsonian Center for Astrophysics, MS 42, 60 Garden Street, Cambridge, MA 02138, USA
[2] Centro Astronómico de Yebes (IGN). Apartado 148, E-19080, Guadalajara, Spain

E-mail contact: mtafalla@cfa.harvard.edu

We present high resolution ($\approx 5''$) NH_3(1,1) and NH_3(3,3) observations towards the blue lobe of the remarkable bipolar outflow L1157. We find that the ammonia emission arises from several compact condensations that are well aligned with IRAS 20386+6751, the origin of the outflow. The gas that emits in ammonia has been strongly affected by the outflow. In addition of having been accelerated, the gas has been heated to temperatures of more than 60-80 K (a factor of 5 with respect to its quiescent value), and its ammonia abundance has been enhanced by more than an order of magnitude. We interpret the ammonia emission as arising from a series of bow shocks along the outflow axis, and although we cannot detect the shocking agent, our observations suggest that it is in the form of a highly collimated jet. The multiplicity of the ammonia peaks along the outflow suggests the jet is episodic, and the emitting source is so reddened, that most likely represents a case of a Class 0 object.

Accepted by Astrophys. J. L.

Protostellar Collapse with a Shock

John C. Tsai[1,2] **and Juliana J. L. Hsu**[3]

[1] NASA Ames Research Center, MS 245–3, Moffett Field, CA 94035, USA
[2] Canadian Institute for Theoretical Astrophysics, McLennan Labs, University of Toronto, 60 St. George St., Toronto, Ont. M5S 1A7, Canada
[3] Theoretical Astrophysics Center, University of California, Berkeley, CA 94720, USA

E-mail contact: tsai@cita.utoronto.ca

We reexamine both numerically and analytically the collapse of the singular isothermal sphere in the context of low mass star formation. We consider the case where the onset of collapse is initiated by some arbitrary process which is accompanied by a central output of either heat or kinetic energy. We find two classes of numerical solutions describing this manner of collapse. The first approaches in time the expansion wave solution of Shu while the second class is characterized by an ever decreasing central accretion rate and the presence of an outwardly propagating weak shock. The collapse solution which represents the dividing case between these two classes is determined analytically by a similarity analysis. This solution shares with the expansion wave solution the properties that the gas remains stationary with a r^{-2} density profile at large radius and that, at small radius, the gas freefalls onto a nascent core at a constant rate which depends only on the isothermal sound speed. This accretion rate is a factor of ~ 0.1 that predicted by the expansion wave solution. This reduction is due in part to the presence of a weak shock which propagates outward at 1.26 times the sound speed. Gas in the postshock region first moves out subsonically but is then decelerated and begins to collapse. The existence of two classes of numerical collapse solutions is explained in terms of the instability to radial perturbations of the analytic solution. Collapse occurring in the manner described by some of our solutions would eventually unbind a finite sized core. However, this does not constitute a violation of the instability properties of the singular isothermal sphere which is unstable both to collapse and to expansion. To emphasize this, we consider a purely *expanding* solution for isothermal spheres. This solution is found to be self–similar and results in a uniform density core in the central regions of the gas. Our solutions may be relevant to the "luminosity" problem of protostellar cores since the predicted central accretion rates are significantly reduced relative to that of the expansion wave solution. Furthermore, our calculations indicate that star forming cloud cores are not very tightly bound and that modest disturbances can easily result in both termination of infall and dispersal of unaccreted material.

Accepted by Astroph. J.

A submm study of the Class 0 protostar HH24MMS

D. Ward-Thompson[1], **R. Chini**[2], **E. Krügel**[2], **P. André**[3] **and S. Bontemps**[3]

[1] Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, UK
[2] Max Planck Institut für Radioastronomie, Auf dem Hügel 69, D–53121 Bonn, Germany
[3] Service d'Astrophysique, Centre d'Etudes de Saclay, 91191 Gif-sur-Yvette Cedex, France

E-mail contact: dwt@roe.ac.uk

Results are presented of a JCMT submillimetre continuum study of the recently discovered candidate protostellar source HH24MMS. New submillimetre flux densities are listed, which were obtained under good weather conditions on Mauna Kea, and the shortest wavelength detection of this source is now 350 μm. The spectrum of HH24MMS is discussed and its implications for the mass, luminosity and evolutionary stage of the source are derived under two different sets of assumptions: (i) a grey-body single temperature fit to the submm spectral energy distribution, and (ii) a radiative transfer calculation with a dust model of icy and fluffy grains and a radial temperature dependence. A VLA continuum source coincident with the submm source indicates an embedded young stellar object, and hence a protostellar source which has passed the ambipolar diffusion phase; the radio spectral index shows the emission to be partly free-free and partly thermal dust. A 450-μm map of HH24MMS shows the source to be unresolved E-W, and partially resolved N-S, with a deconvolved FWHM of 21 arcsec. The total mass of HH24MMS under this gaussian is found to be $\sim$4–9$M_\odot$ under the single temperature assumption, and $\sim$4–8$M_\odot$ under the radiative transfer model assumptions, consistent with virial mass estimates from $C^{18}O$ linewidths. If the higher values are correct, they may be indicating partial gas freezing onto dust grains. Because of the absence of far IR data the total luminosity is still uncertain. We can place an upper limit of 20$L_\odot$ from the IRAS upper limits. The single temperature assumption

yields a best estimate of the total luminosity of $5.3L_{\odot}$. The radiative transfer model attempts to separate the two contributions to this luminosity of external heating and internal heating, and suggests an upper limit to the luminosity of the central protostellar source of $2.5L_{\odot}$. We use the ratio of total to submillimetre luminosity to determine the appropriate classification of a YSO, finding a value of this ratio for this source of <40, well below the Class 0 upper limit of 200. Hence we confirm that HH24MMS is a Class 0 protostar, which is at the beginning of the protostellar accretion phase.

Accepted by MNRAS

Dissertation Abstracts

Herbig Ae/Be Stars: An Investigation of Molecular Environments and Associated Stellar Populations

Lynne A. Hillenbrand

Thesis work conducted at: University of Massachusetts

Current address: University of California; Dept. of Astronomy; 601 Campbell Hall; Berkeley, CA 94720

Electronic mail: lynne@astron.berkeley.edu

Ph.D dissertation directed by: Stephen E. Strom

Ph.D degree awarded: 1995, February

We have carried out a molecular mapping, optical and infrared imaging, and stellar-classification spectroscopic survey of star-forming sites containing young ($\tau < 1$ Myr) intermediate- and high-mass ($M > 3M_{\odot}$) stars. Our target sample is drawn from the set of pre-main sequence Herbig Ae/Be stars with spectral types earlier than B7, and focusses on those which are isolated from large complexes of extensive star-formation. Our aim is to quantify the local environmental characteristics (molecular and stellar clustering) of regions in which high-mass stars are being produced, in order to compare these properties with those of regions in which only low-mass stars are being produced.

In the current analysis, we first investigate the general attributes of the small clouds within which our sample of massive Ae/Be stars is found. We then define an appropriate size scale (1/3 pc $\times$ 1/3 pc in area) over which to investigate stellar clustering properties, and identify small (a few to tens in number), dense (several hundred to several thousand stars per cubic parsec), partially - obscured stellar aggregates projected onto the same molecular cores as are our sample of Ae/Be stars. We find an apparent correlation between cluster density and the mass of the defining Ae/Be star. We then present evidence based on the observation of infrared and spectroscopic circumstellar activity signatures usually indicative of stellar youth, as well as on the actual location of the members of several of these groups in the HR diagram, that indeed the companions to young massive Ae/Be stars are also young pre-main sequence stars, of lower mass. Given the significant amount of ambient molecular material and the apparent youthfulness of the stellar populations, any and all objects found near the cores are likely not to have wandered far from their birthplaces. Thus, our survey enables us to carry out a complete census of stars formed relatively contemporaneously with the high-mass "signpost."

Our particular goals then, are to determine 1) *the initial stellar mass spectrum* in spatially and temporally coherent (*i.e.*, truly "initial") units which have given birth to at least one high-mass star, as well as 2) *the time sequence of star formation as a function of stellar mass*, that is, whether stars of all masses are formed simultaneously in a dense stellar environment, or whether high-mass stars might form significantly before or after the initiation of low-mass star-formation. With these goals, we explore techniques for investigating the distributions of stellar masses and stellar ages in young groups, as well as the observational and theoretical limits of these techniques.

Finally, in our discussion we address the issue of differences in local stellar environment between star-forming regions producing high-mass stars and those producing only low-mass stars. We pursue the hypothesis that if the Ae/Be stars studied herein are representative of a stellar evolutionary phase through which all young high-mass stars pass, and if their association with dense aggregates of stars is typical, then these young stellar *systems* may provide important clues to the physical processes associated with forming high-mass stars. We therefore urge the theoretical consideration of star formation in dense groups (≈ 1000 *stars* pc^{-3}) as an expansion to the developing theory of protostellar collapse for individual high-mass stars.

The Kinematics of Circumstellar Disks around T Tauri Stars

David W. Koerner

Thesis work conducted at: California Institute of Technology

Current address: 169-506 Jet Propulsion Laboratory, Pasadena, CA 91009

Electronic mail: davidk@coma.jpl.nasa.gov

Ph.D dissertation directed by: A. I. Sargent

Ph.D degree awarded: September 1994

Aperture synthesis images of molecular gas around the T Tauri stars, GM Aurigae, RY Tauri, DL Tauri, DO Tauri, and AS 209 are interpreted with the aid of a kinematic model of a circumstellar disk. The velocity structure and morphology of the gas strongly suggest that circumstellar disks with radii of a few hundred AU are present around all five stars. Explicit identification of kinematic patterns in the spectral line maps is achieved for the two largest disks, GM Aur and DO Tau.

Maps of the relatively old T Tauri star, GM Aur, in the ^{13}CO(2→1) line at 4″ resolution reveal compact gas associated with the stellar position and at the core of a larger rotating gaseous disk, 950×530 AU in extent. The mean velocity gradient across the disk, which is oriented along PA $\approx 50°$, is consistent with rotation about an axis at PA = 140°. The structure observed in ^{13}CO aperture synthesis maps agrees well with synthetic maps of the gas emission generated from a model. For a disk that is inclined 30° from face on, in Keplerian rotation, a 0.80 $M_\odot$. central mass (star + disk), a systemic velocity, V_{HEL}, of 15.38 km/s., and a mass, 0.1 $M_\odot$. is derived.

A survey of T Tauri stars for circumstellar molecular gas also yields evidence for rotating disks. RY Tau, DL Tau, DO Tau, and AS 209 are detected in CO(2→1) emission elongated along PA $\approx 48°, 84°, 160°$, and 138°, respectively, with deconvolved half-maximum radii of 110, 250, 350, and 290 AU in aperture synthesis images at $\sim$ 2-3″ resolution. Three of these, RY Tau, DL Tau, and AS 209, exhibit velocity gradients parallel to this direction in first moment velocity maps, suggesting rotation of the circumstellar gas. Spectra of RY Tau and AS 209 exhibit a characteristic double-peaked shape, but that of DO Tau is dominated by the presence of high-velocity blue-shifted gas. DL Tau's spectrum has a linewidth that is too narrow (ΔV = 1 km/s.) to be resolved into double peaks. Position-Velocity Diagrams (PVDs) constructed parallel and perpendicular to the axis of elongation imply rotation and infall or outflow, respectively. Those for RY Tau, DL Tau, and AS 209 show predominantly rotation, but some evidence of an orthogonal gradient (infall or outflow) is seen for RY Tau and AS 209. In contrast, the PVDs for DO tau suggest that its molecular emission originates predominantly from outflow or infall.

Recent evidence of infall in circumstellar gas around T Tauri stars has motivated construction of a kinematic model of molecular emission from a disk of rotating and infalling gas. The velocity structure of the model disk assumes that infalling gas obeys angular momentum conservation on ballistic trajectories until it reaches the radial value, R_{disk}, where the magnitude of the rotational velocity component reaches the Keplerian value. For $R < R_{disk}$, gas is assumed to be in circular Keplerian orbits. Synthetic spectral line maps are generated by the model and cross-correlated with aperture synthesis maps for a range of the free parameters, including R_{disk}. The best-fit value of R_{disk} for RY Tau, DL Tau, and AS 209, approximately matches that of the outer radius of their emission, indicating these disks are predominantly in Keplerian rotation. However, emission from these stars is marginally resolved and uncertainties in the best-fit parameters are correspondingly high. In contrast, kinematic patterns are well-resolved in emission from DO Tau found in maps within a narrow, near-systemic velocity range. These are best matched by simulations from a model disk with R_{disk} = 350 AU and an outer radius of 500 AU. This result strongly suggests that, in this case, infall from the molecular cloud onto a rotating disk is still in progress.

Mid-Infrared Spectropolarimetry of Molecular Cloud Sources: Magnetic Fields and Dust Properties

Christopher Mathew Wright

Thesis work conducted at: University College, University of New South Wales, Australian Defence Force Academy

Current address: Max-Planck-Institut für Extraterrestrische Physik, Postfach 1603, D-85740 Garching, Germany

Electronic mail: wright@mpe-garching.mpg.de

Ph.D dissertation directed by: Professors D.K. Aitken and A.R. Hyland

Ph.D degree awarded: December 1994

One of the earliest phases of the star formation process is the bipolar outflow, in which two oppositely directed jets of material emanate from the very near vicinity of a deeply embedded YSO. Accompanying these outflows are circumstellar disks of gas and dust, extending in a plane orthogonal to the outflow axis. It is not presently understood how the outflow is generated, but a number of theories propose that a dynamically important magnetic field, embedded in the disk and acting in concert with rotation, is able to tap the gravitational potential well of the star plus disk system to drive material off the disk surface.

Two specific hydromagnetic disk models have received the most attention in the literature. One is whereby an hourglass shaped magnetic field configuration, frozen-in to and threading the disk, co-rotates with it so that partially ionized material is centrifugally accelerated off the disk surface along the field lines. The second is whereby the threading and frozen-in field becomes wound up in the plane of the disk by differential rotation, allowing a magnetic pressure gradient, directed outward along the poles, to accelerate material off the disk surface. The difference in the disk magnetic field configuration predicted by each model suggests that observations of the field may aid in discriminating between them.

Spectropolarimetric observations between 8 and 13μm provide information on the chemical and physical nature of dust grains, as well as on the direction of the transverse (to the line-of-sight) component of an aligning magnetic field. In this thesis, such observations toward a selection of mainly high mass YSOs are presented. The field directions inferred from the polarization position angle are compared with the axes of disks and bipolar outflows associated with the sources. A strong correlation is found such that the field tends to lie in the plane of the disk, thereby providing support for the magnetic pressure mechanism for bipolar outflows.

The observed field directions are also compared with the interstellar field configuration determined from optical polarization of field stars and obtained from the literature. Two distributions are observed, one in which the difference between the position angles of the two fields is less than 30°, and the other for which the difference is greater than 30°. The existence of the second group implies that the evolution of the YSO has a significant perturbing effect on its ambient magnetic field. Together with the disk field finding, the results are discussed in terms of the initial collapse phase of the molecular cloud in which the YSO is embedded, specifically whether the cloud was supercritical or subcritical. For instance, for 2 high mass objects, AFGL 2591 and AFGL 989, and one low mass object, SVS13, the source and interstellar fields, and interstellar field and disk major axes, are inclined by $> 60°$, whilst the source field lies in the disk plane. This implies that the respective clouds have initially collapsed along the primitive magnetic field direction to form the disks, consistent with a subcritical collapse scenario. Within the disks there must exist a significant ionization fraction, such that the field becomes frozen-in. Contraction plus differential rotation then act to wind the field up in the disk plane, thereby magnetically braking its rotation.

A further component of this thesis relates to the properties of the polarizing dust. As well as deriving a new 8-13μm dust grain emissivity function, the evidence for a new absorption feature at $\sim$11.15μm, and its possible interpretation in terms of a crystalline component, is discussed. Additionally, the 8-13μm polarization profiles of a number of sources, including those embedded in molecular clouds and behind large column depths of the ISM, are compared with the profile of the BN Object, usually taken as a standard. Differences between the respective profiles are interpreted in terms of differing contributions from icy grain mantles to the polarization.

New Jobs

Post Doctoral Research Associate:
Star Formation; IR/mm-wave Instrumentalist/Observer

Applications are invited for a postdoctoral position at the Center for Astrophysics and Space Astronomy in the Astrophysical, Planetary, and Atmospheric Sciences Department at the University of Colorado.

We are seeking a person who can help support a research program in star formation and the interstellar medium. The successful applicant should have a working knowledge of visual, near-infrared, and/or millimeter-wave wavelength observing methods and data reduction techniques. The primary areas of research include searches for and detailed investigation of outflows from young stars, the impact of these outflows on the surrounding interstellar medium, the structure and kinematics of molecular clouds, the origin of molecular clouds, and general studies of the interstellar medium and young stars.

We also hope to build-up an instrumental program in technologies relevant to star formation. Therefore, we will give preference to candidates with strong instrumentation skills who can help our group develop proposals for new infrared and mm-wavelength instrumentation and who can supervise the construction of such hardware.

The initial appointment will be for a two year period, with a possible extension for a third year. The appointment will start during summer or fall of 1995. Applicants should have, or expect to have by summer 1995, a Ph.D. in Astronomy, Physics, or a related field. The applicant will be expected to collaborate with Dr. John Bally, his students, and other faculty and staff.

Please send a curriculum vitae, complete publication list, a letter stating the candidate's research interests and experience, and the names, addresses (postal and e-mail), and telephone numbers of three professional references to Dr. John Bally, CASA, Campus Box 389, University of Colorado, Boulder, CO 80309. Deadline for application is May 1, 1995.

The University of Colorado strongly supports the principle of diversity. We are particularly interested in receiving applications from women, ethnic minorities, disabled persons, and veterans.