THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

No. 69 — 21 June 1998 Editor: Bo Reipurth (reipurth@casa.colorado.edu)

Abstracts of recently accepted papers

Dense Cores in Dark Clouds. XI. A Survey for N_2H^+, C_3H_2 and CCS

Priscilla J. Benson[1], Paola Caselli[2] and Philip C. Myers[3]

[1] Science Fellow, Bunting Institute; Permanent Address: Whitin Observatory, Wellesley College, 106 Central Street, Wellesley, MA 02181-8286, USA
[2] Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy
[3] Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: pbenson@wellesley.edu

We have used the 3 mm receiver and upgraded antenna of Haystack Observatory to make high spatial and spectral resolution observations of lines of N_2H^+ and C_3H_2 in 60 dense cores. Both species are detected in most of the cores, and the velocities and line widths are well-correlated. This suggests that ions and neutrals are well coupled. We found $v_{\rm D,max} \leq 0.03$ km s^{-1} which is the first observational constraint on the relative speed of ions and neutrals in star-forming dense cores. Twenty of the cores were also observed in the $J_{\rm N} = 4_3$–3_2 line of CCS. From our N_2H^+ observations, the fractional abundance of the molecular nitrogen N_2 is found to be $\simeq 7{\times}10^{-5}$, consistent with all the nitrogen being in molecular form and not depleted onto dust grains.

Accepted by ApJ

Preprints available from http://www.arcetri.astro.it/science/SF/

Magnetospheric accretion and PMS stellar masses

Ian A. Bonnell[1], Kester W. Smith[2], Michael R. Meyer[3], Christopher A. Tout[1], Daniel F. M. Folha[2,4] and James P. Emerson[2]

[1] Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK
[2] Queen Mary and Westfield College, Mile End Road, London, E1 4NS, UK
[3] Hubble Fellow, Steward Observatory, University of Tucson, AZ 85721, USA
[4] Centro de Astrofisica da Universidade do Porto, Rua do Campo Alegre, 823, 4150 Porto, Portugal

E-mail contact: bonnell@ast.cam.ac.uk

We present a method of determining lower limits on the masses of pre-main-sequence (PMS) stars and so constraining the PMS evolutionary tracks. This method uses the red-shifted absorption feature observed in some emission-line profiles of T Tauri stars indicative of infall. The maximum velocity of the accreting material measures the potential energy at the stellar surface, which, combined with an observational determination of the stellar radius, yields the stellar mass. This estimate is a lower limit owing to uncertainties in the geometry and projection effects. Using available data, we show that the computed lower limits can be larger than the masses derived from PMS evolutionary tracks for $M \lesssim 0.5 M_\odot$. Our analysis also supports the notion that accretion streams do not impact near the stellar poles but probably hit the stellar surface at moderate latitudes.

Accepted by MNRAS

Preprints available from astro-ph/9805286

A Multi-Wavelength Study of the Sharpless 151 Region

J. Brand[1] **and J.G.A. Wouterloot**[2,3]

[1] Istituto di Radioastronomia, C.N.R., Via Gobetti 101, I-40129 Bologna, Italy
[2] Radioastronomisches Institut, Univ. zu Bonn, Auf dem Hügel 71, D-53121 Bonn, Germany
[3] I. Physikalisches Institut, Univ. zu Köln, Zülpicher Strasse 77, D-50937 Köln, Germany

E-mail contact: brand@astbo1.bo.cnr.it; jwouterl@astro.uni-bonn.de

Results are presented of an extensive, multi-wavelength study of the area around the evolved HII region Sh 2-151. We discuss the excitation of the HII region, and analyze its interaction with molecular clouds in the vicinity, the clouds themselves, and their embedded objects.

We present KOSMA 3-m ^{12}CO(2–1) and (3–2) observations of a $26' \times 46'$ region around Sh 2-151. These observations reveal five clouds, with a total mass of 2.9×10^4 $M_\odot$. A small ($2' \times 4'$) region to the SW of Sh 2-151 was mapped in several CO and CS transitions with the IRAM 30-m telescope. The latter region contains 1.8×10^3 $M_\odot$ of molecular mass, and hosts an IRAS- and H_2O maser source (WB89-234). Tracers of higher (column-) densities, such as $C^{18}O$ and CS, show the existence of two clumps ($N(H_2) \approx 1 - 2 \times 10^{22}$ cm^{-2}) connected by a ridge of warm ($T_{kin} \sim 36$ K) narrow-line ($\Delta v(^{12}CO) < 1$ km s^{-1}) gas. The southern clump contains the IRAS/maser source, exhibits a molecular outflow (M$\approx$5 $M_\odot$, $\tau_{dyn} \approx 2 \times 10^5$ yr), and is therefore probably a region of active star formation. In the northern clump the line profiles have an intermediate width (1–3 km s^{-1}; partly due to the presence of two emission components) and are non-gaussian (shoulders, wings) at several positions. IRAS (HIRES) observations show there is also FIR emission associated with the northern clump.

NIR (J, H, K, H_2) observations show the presence of several red star-like objects and diffuse emission in both clumps; some of the diffuse emission is stronger and more extended in K and H_2, and may be due to dust emission around embedded objects.
HIRES data reveal that IRAS23004+5642 (WB89-234) nearly coincides with the H_2O maser and the outflow, and not with the strong, narrow-line CO-emitting gas detected towards the point source catalog position. The linewidth of this relatively low-density warm gas, the heating source of which is as yet unknown, indicates the absence of dynamical interaction with both Sh 2-151 and the embedded IR sources.
¿From the HIRES 60μm and 100μm data we derive dust temperatures of 30–40 K, the highest values occurring near the maser, and a dust mass of $\sim$30 $M_\odot$; assuming a gas-to-dust ratio of 100, this implies we detect $\sim$10% of the dust. Evidence from the available (literature) data leads to the conclusion that the exciting star(s) of Sh 2-151 has (have) not yet been identified. We suspect that one or more early type (<B0) stars may be hidden behind the molecular cloud associated with WB89-234. The ionized gas mass of Sh 2-151 is $\sim$700 $M_\odot$.
Star formation in the Sh 2-151 area may occur in the whole region of strong FIR emission (as seen in the HIRES maps: $\sim$0.5 degrees, or 50 pc, in length); north of Sh 2-151, activity is seen near the edge of a large (20 pc diameter) molecular cloud.

Accepted by Astron. & Astroph.

The circumstellar envelopes around three protostars in Taurus

Claire J. Chandler[1], **Mary Barsony**[2] **and Toby J. T. Moore**[3]

[1] Mullard Radio Astronomy Observatory, Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, UK
[2] Physics Department, University of California, Riverside, CA 92521, USA
[3] Astrophysics Research Institute, Liverpool John Moores University, Byrom Street, Liverpool L3 3AF, UK

E-mail contact: cjc@mrao.cam.ac.uk

We have investigated the distribution of circumstellar material around three Class I protostars in Taurus. TMC1 (IRAS 04381+2540), TMC1A (IRAS 04365+2535), and Haro 6-10 (IRAS 04263+2426) have all been mapped in 790 μm dust continuum emission using the James Clerk Maxwell Telescope, and TMC1A has also been imaged at λ 1.1 mm. In addition, we present a ^{12}CO J=2–1 map of Haro 6-10 obtained using the Caltech Submillimeter Observatory. The dust emission from TMC1 is extended and is oriented perpendicular to its outflow, with little evidence for a compact disc component. The submillimetre emission from TMC1A is centrally peaked, with a weak extension in the direction of the outflow at both 790 μm and 1.1 mm. It is possible that the interaction of the outflow with the surrounding cloud is heating the dust. The emission from Haro 6-10 is oriented roughly perpendicular to the direction of several

HH objects in the region. There is no clear bipolar molecular outflow structure in the CO(2–1) map, and the relatively low velocities observed in the line wings suggest that any such system must lie close to the plane of the sky.

If the dust emission from the envelopes is optically thin and a temperature distribution can be specified, the broadband spectral energy distribution (SED) can be used to constrain the density profile. We isolate the envelope SEDs for our sources by subtracting possible disc and wind components from the submillimetre flux densities, and use a simple model to derive the radial power-law dependence of the density in each case. We find that for a density distribution $\rho \propto r^{-p}$ the values of p are 0.93 ± 0.25, 0.81 ± 0.30, and 1.22 ± 0.11 for TMC1, TMC1A and Haro 6-10 respectively, which for all but Haro 6-10 is considerably shallower than can currently be explained by collapse theory. We suggest that the envelopes around TMC1 and TMC1A may be rotationally supported, but that the Haro 6-10 envelope may still be infalling. The envelope masses are ~ 0.02–0.03 $M_\odot$ in all cases.

Accepted by MNRAS.

Preprint available at http://www.mrao.cam.ac.uk/∼cjc

The chemical signature of magnetohydrodynamic waves in molecular clouds

S. B. Charnley[1,2]

[1] Astronomy Department, University of California, Berkeley, CA 94720, U.S.A.
[2] Space Science Division, MS 245–3, NASA Ames Research Center, Moffett Field, CA 94035, U.S.A.

E-mail contact: charnley@dusty.arc.nasa.gov

By considering the propagation of low-amplitude magnetohydrodynamic waves in partially ionized plasmas it is shown that the ion-neutral drift (ambipolar diffusion) induced by the waves can have specific effects on the molecular chemistry of cold material. The chemistry occurring in gas swept by Alfvén waves is described and it is shown that this leads to spatial variations in the deuterium fractionation ratios of, for example, HCO^+ and N_2H^+, on spatial scales of a few hundredths of a parsec, depending upon the fractional ionisation of the ambient medium. The possibility of detecting interstellar Alfvén waves by molecular spectroscopy and their effect of producing small-scale chemical abundance gradients in molecular clouds are briefly discussed.

Accepted by M.N.R.A.S.

A textbook case of bow shock entrainment in a YSO outflow

C.J. Davis[1,2], **M.D. Smith**[3], **G.H. Moriarty-Schieven**[1]

[1] Joint Astronomy Centre, 660 N. A'ohōkū Place, University Park, Hilo, Hawaii 96720, U.S.A.
[2] Dublin Institute for Advanced Studies, School of Cosmic Physics, 5 Merrion Square, Dublin 2, Ireland
[3] Astronomisches Institut, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

E-mail contact: cdavis@jach.hawaii.edu

Near-IR images in H_2 line-emission and submillimeter maps in CO J=3-2 emission illustrate the remarkable association between a molecular bow shock and the red-shifted molecular outflow lobe in W 75N. The flow lobe fits perfectly into the wake of the bow, as one would expect if the lobe represented swept-up gas. Indeed, these observations strongly support the "bow shock" entrainment scenario for molecular outflows driven by young stars.

The characteristics of the bow shock and CO outflow lobe are compared to those of numerical simulations of jet-driven flows. These models successfully reproduce the bulge and limb-brightening in the CO outflow, although the model H_2 bow exhibits more structure extending back along the flow axis. We also find that the size of the flow, the high mass fraction in the flow at low outflow velocities (low γ values), and the high CO/H_2 luminosity ratio indicate that the system is evolved. We also predict a correlation, in evolved systems, between outflow age and the CO/H_2 luminosity ratio.

Accepted by MNRAS

Preprints available from: http://www.jach.hawaii.edu/∼cdavis/papers.html

A survey of SiO emission towards interstellar masers

J. Harju[1], K. Lehtinen[1], R.S. Booth[2] and I. Zinchenko[3]

[1] Observatory, P.O. Box 14, FIN-00014 University of Helsinki, Finland
[2] Onsala Space Observatory, S-43992 Onsala, Sweden
[3] Institute of Applied Physics of the Russian Academy of Sciences, 46 Uljanov St., 603600 Nizhny Novgorod, Russia

E-mail contact: harju@obs20.astro.helsinki.fi

We have conducted a survey of SiO emission towards galactic H_2O and OH masers and ultracompact HII regions using the 15-m SEST and the 20-m Onsala telescope. With the SEST the transitions ($v = 0, J = 2-1$) and ($v = 0, J = 3-2$) of SiO at 3 and 2 mm were measured simultaneously. With Onsala only the ($v = 0, J = 2 - 1$) line was accessible. Altogether 369 objects were observed and SiO was detected towards 137 of them. The detection rate is highest towards the most intense H_2O masers, which probably require powerful shocks to be excited. The SiO detection rate correlates also with the integrated far-infrared flux density and the FIR luminosity of the associated IRAS point source, indicating that the occurrence of shocks is related to the amount of radiation from the central stellar source(s). For flux and luminosity limited samples the SiO detection rate is higher in the inner 7 kpc from the galactic centre than elsewhere. This suggests that dense cores belonging to the so called 'molecular ring' provide particularly favourable conditions for the production of gaseous SiO.

The full widths above 2σ of the SiO($J = 2 - 1$) lines, which are likely to be related to the associated shock velocities, range from 2 to 60 $\mathrm{km\,s^{-1}}$ except for the line in Ori KL which has a full width of about 100 $\mathrm{km\,s^{-1}}$. The median of our sample is 19 $\mathrm{km\,s^{-1}}$. The SiO lines are single-peaked and the peak velocities are always close to the ambient cloud velocity as determined from published CS observations. These line characteristics are compared with the predictions of kinematical bow-shock models. The SiO line shapes correspond with the model of Raga & Cabrit (1993) where the emission arises from turbulent wakes behind bow-shocks. However, the number of symmetric, relatively narrow profiles indicates that at least in some of the observed sources SiO emission arises also from the quiescent gas component.

We suggest that this is due to evaporation of silicon compounds from grain mantles and their reprocessing to SiO in dense quiescent gas according to the model of McKay (1995,1996). These reactions may be initiated and sustained by ionizing radiation from shocks, in the same way as the enhancement of HCO^+ near Herbig-Haro objects has been explained in the model of Wolfire & Königl (1993).

The excitation temperatures of SiO($J = 2 - 1$) and ($J = 3 - 2$) transitions were determined towards three strong sources using measurements in isotopically substituted SiO. In all three sources the transitions are clearly subthermally excited, implying moderate densities ($< 3\,10^6$ $\mathrm{cm^{-3}}$) in the SiO emission regions.

Accepted by A&A Suppl.

Infrared imaging and millimetre continuum mapping of Herbig Ae/Be and FU Orionis stars

Th. Henning[1], A. Burkert[1], R. Launhardt[1], Ch. Leinert[2] and B. Stecklum[3]

[1] Astrophysical Institute and University Observatory Jena, Schillergäßchen 2-3, D-07745 Jena, Germany
[2]MPIA Heidelberg, Königstuhl 17, D-69117 Heidelberg, Germany
[3]State Observatory of Thuringia, Sternwarte 5, D-07778 Tautenburg, Germany

E-mail contact: henning@astro.uni-jena.de, alf@astro.uni-jena.de

The goal of this paper is a detailed analysis of the dusty environment of Herbig Ae/Be stars and FU Orionis objects. For this purpose we mapped 22 regions at 1.3 mm wavelength containing 25 target objects. We found that it is indispensable to perform mapping in contrast to pointed On-On measurements in order to obtain the correct distribution of cold material around young stellar objects and to relate 1.3 mm flux densities to individual sources. To get reliable information about the structure and shape of the dust configurations and their relation to the stellar sources, we superimposed the millimetre maps on near-infrared images. The comparison of the data demonstrated that some of the Herbig Ae/Be stars are not associated with the peak of the millimetre emission. This is obviously the case for V 376 Cas/LkHα 198, MWC 137, CoD-42°11721, and V 1685 Cyg/V 1686 Cyg.

We found two different morphologies of the dust envelopes: 6 regions show a compact structure, whereas 12 regions are characterized by a core/envelope structure. The "disk" objects AB Aur and HD 169236 show only a compact core

and are not surrounded by an extended envelope. We did not detect HK Ori, HD 250550, LkHα 25, and V 1515 Cyg which all have low IRAS luminosities.

Based on the flux densities derived from the millimetre maps, we estimated characteristic physical parameters like density and mass assuming optically thin emission. The total masses of the circumstellar regions around the Herbig Ae/Be stars with core/envelope structure and with "genuine" point-like millimetre sources are $80\pm60\,M_\odot$ and $0.15\pm0.15\,M_\odot$, respectively. The lowest and highest masses of the circumstellar material were found around AB Aur ($0.03\,M_\odot$) and CoD-42°11721 ($1100\,M_\odot$), respectively. The average densities in the cores range from 10^5 to $10^8\,cm^{-3}$. The densities of the extended envelopes are of the order of 10^4 to $10^5\,cm^{-3}$.

In addition, we combined the measured millimetre flux densities with infrared and optical data and modelled the broad-band spectral energy distributions using spherically symmetric models. We found good fits for both the core sources (AB Aur, V 1331 Cyg) and the core/envelope objects (VY Mon, LkHα 234) we considered for modelling. The parameters derived this way are generally in good agreement with data directly derived from the maps. However, the possibility to fit the spectral energy distribution of AB Aur which is known to be associated with a disk clearly demonstrates that a good "spherical" fit cannot be used as an argument against the presence of a disk.

Accepted by Astron. & Astrophys.

The Nature of Isolated T Tauri Stars

Wilhelm Hoff, Thomas Henning and Werner Pfau

Astrophysikalisches Institut und Universitäts-Sternwarte Jena, Schillergäßchen 2, D-07745 Jena, Germany

example: E-mail contact: hoff@astro.uni-jena.de

We present the results of a search for young stellar objects around the two isolated T Tauri stars (TTSs) TW Hya and CoD−29°8887. From the spectroscopic properties of these two objects, it is obvious that they are T Tauri stars, although they are not associated with a star-forming region as it is the case for most of the known TTSs. Especially TW Hya is the only classical TTS that is not located in a dark cloud with star formation activity. The same is true for the weak-line T Tauri star CoD−29°8887.
We searched for pre-main sequence stars using ROSAT PSPC observations pointing at our two main targets. With a sophisticated search strategy we could identify 107 X-ray sources in our fields. For the 37 stellar-like optical counterparts we did spectroscopic follow-up observations. These show that within the viewing field of ROSAT there are no other X-ray emitting young stellar objects around TW Hya and CoD−29°8887.
For the isolated TTSs TW Hya and HD 98800 Hipparcos parallax measurements are available locating them at distances of 56 and 46pc, respectively. This means that they are the closest TTSs with circumstellar dusty disks known today. The space velocities of these two objects are 3–5km/sec. From their position in the HR diagram, we obtained an age of about 10^7 years. Hence, we conclude that these two objects travelled not far away from their original birthplace and their parental molecular cloud dispersed meanwhile. This is the solution why these T Tauri stars appear to be isolated.

Accepted by Astronomy & Astrophysics

A dust disk surrounding the young A star HR4796A

Ray Jayawardhana[1], Scott Fisher[2], Lee Hartmann[1], Charles Telesco[2], Robert Pina[2] and Giovanni Fazio[1]

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA
[2] Department of Astronomy, University of Florida, Gainesville, FL 32611, USA

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

We report the codiscovery of the spatially-resolved dust disk of the Vega-like star HR 4796A. Images of the thermal dust emission at $\lambda = 18\,\mu$m show an elongated structure approximately 200 AU in diameter surrounding the central A0V star. The position angle of the disk, $30° \pm 10°$, is consistent to the position angle of the M companion star, 225°, suggesting that the disk-binary system is being seen nearly along its orbital plane. The surface brightness distribution of the disk is consistent with the presence of an inner disk hole of approximately 50 AU radius, as was originally suggested by Jura et al. on the basis of the infrared spectrum. HR 4796 is a unique system among the Vega-like or β

Pictoris stars in that the M star companion (a weak-emission T Tauri star) shows that the system is relatively young, $\sim 8 \pm 3$ Myr. The inner disk hole may provide evidence for coagulation of dust into larger bodies on a timescale similar to that suggested for planet formation in the solar system.

Accepted by The Astrophysical Journal Letters

Photoevaporation of protostellar disks: III. The appearance of photoevaporating disks around young intermediate mass stars

Olaf Kessel[1], Harold W. Yorke[2] and Sabine Richling[3]

[1] Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany
[2] Jet Propulsion Laboratory, Pasadena, CA, USA
[3] Astronomisches Institut der Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

E-mail contact: kessel@mpia-hd.mpg.de

We present theoretical continuum emission spectra (SED's), isophotal maps and line profiles for several models of photoevaporating disks at different orientations with respect to the observer. The hydrodynamic evolution of these models has been the topic of the two previous papers of this series. We discuss in detail the numerical scheme used for these diagnostic radiation transfer calculations. Our results are qualitatively compared to observed UCHII's. Our conclusion is that the high fraction of "unresolved" UCHII's from the catalogues of Wood & Churchwell (1989) and Kurtz et al. (1994) cannot be explained by disks around massive stars. In particular, the observed infrared spectra of these objects indicate dust temperatures which are about one order of magnitude lower than expected. We suggest that disks around close companions to OB stars may be necessary to resolve this inconsistency. Alternatively, strong stellar winds and radiative acceleration could remove disk material from the immediate vicinity of luminous O stars, whereas for the lower luminosity sources considered here this will not occur. We also find that line profiles tracing the evaporated material originating from the disk are not influenced significantly by the existence of stellar winds over a wide range of wind velocities (400 - 1000 $\mathrm{km\,s^{-1}}$). We compare our results to the bright IRAS source MWC 349 A. Many of its properties, especially its spatial appearance in high-resolution radio maps, can be well explained by a disk surrounding a UV luminous star with a high velocity stellar wind.

Accepted by Astronomy and Astrophysics

Mid-infrared Imaging of a Circumstellar Disk Around HR 4796: Mapping the Debris of Planetary Formation

D.W. Koerner[1,2], M.E. Ressler[1], M.W. Werner[1], and D.E. Backman[3]

[1] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, USA
[2] University of Pennsylvania, 4N14 DRL, 209 S. 33rd St., Philadelphia, PA 19104-6396, USA
[3] Franklin & Marshall College, Dept. of Physics & Astronomy, PO Box 3003, Lancaster, PA 17604-3003, USA

E-mail contact: davidk@uraniborg.physics.upenn.edu

We report the discovery of a circumstellar disk around the young A0 star, HR 4796, in thermal infrared imaging carried out at the W.M. Keck Observato ry. By fitting a model of the emission from a flat dusty disk to an image at $\lambda = 20.8$ μm, we derive a disk inclination, $\iota = 72^{\circ}{}^{+6^{\circ}}_{-9^{\circ}}$ from face on, with the long axis of emission at PA $28^{\circ} \pm 6^{\circ}$. The intensity of emission does not decrease with radius as expected for circumstellar disks but *increases* outward from the star, peaking near both ends of the elongated structure. We simulate this appearance by varying the inner radius in our model and find an inner hole in the disk with radius $R_{in} = 55 \pm 15$ AU. This value corresponds to the radial distance of our own Kuiper belt and may suggest a source of dust in the collision of cometesimals. By contrast with the appearance at 20.8 μm, excess emission at $\lambda = 12.5$ μm is faint and concentrated at the stellar position. Similar emission is also detected at 20.8 μm in residual subtraction of the best-fit model from the image . The intensity and ratio of flux densities at the two wavelengths could be accounted for by a tenuous dust component that is confined within a few AU of the star with mean temperature of a few hundred degrees K, similar to that of zodiacal dust in our own solar system. The morphology of dust emission from HR 4796 (age 10 Myr) suggests that its disk is in a transitional planet-forming stage, between that of massive gaseous proto-stellar disks and more tenuous debris disks such as the one detected around Vega.

Accepted by Astrophys. J. Letters

Spectroscopic classification of X-ray selected stars in the ρ Ophiuchi star-forming region and vicinity

E. L. Martín[1,2], T. Montmerle[3], J. Gregorio-Hetem[4] and S. Casanova,[3]

[1] Astronomy Department, University of California, Berkeley, CA 94720, USA
[2] Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain
[3] Service d'Astrophysique, CEA/DSM/DAPNIA/SAp, Centre d'Etudes de Saclay, 91191 Gif-sur-Yvette Cedex, France
[4]Universidade de Sao Paulo - IAG/USP, Depto. de Astronomia C.P. 9638 - CEP01065 - São Paulo, SP - Brazil

E-mail contact: ege@popsicle.berkeley.edu

We present intermediate-resolution (FWHM∼1.5–2.6 Å) optical spectra of 106 candidate optical counterparts of 77 X-ray sources detected in four pointed (t_{exp} ≥8700 s) *ROSAT* PSPC observations of the ρ Ophiuchi star-forming region and vicinity. Using the spectral types and equivalent widths of H_α and Li Iλ670.8 nm obtained from our spectra, we applied spectroscopic criteria to classify our sample in different pre-main sequence subtypes: 'classical' T Tauri stars (CTTS); 'weak' T Tauri stars (WTTS), and 'post' T Tauri stars (PTTS). A total of 10 CTTSs, 43 WTTSs and 6 PTTSs were found among the PSPC-selected stars. Our results more than double the number of pre-main sequence stars spectroscopically identified in the ρ Ophiuchi region.

We considered regions with different molecular cloud properties: the central core and the outer ring of the ρ Ophiuchi dark cloud (L1688); the 'streamers' (L1709); the R7 clump; and the 'smoke rings'. In the inner field of L1688, the ratio of WTTSs over CTTSs is ∼1:1, significantly smaller than in the other regions (4:1 in the outer ring of L1688 and 5:1 in the smoke rings). The WTTS/CTTS ratio in the R7 field is the highest of our survey (10:1). We argue that this could be due to the UV radiation from the nearby massive binary ρ Oph AB, and/or winds from the Upper Sco OB association, which might shorten the lifetime of the circumstellar disks of the low-mass stars.

We find no PTTS in the inner field of our L1688 PSPC image, and only 3 PTTSs in the outer ring despite the high sensitivity of our X-ray observations in this region. This result confirms that the central region of L1688 is extremely young (age<5 Myr), as suggested by near-infrared surveys. The presence of a small number of PTTSs scattered around the ρ Ophiuchi molecular clouds suggests that star formation may have been going on for 10 to 30 Myr, very slowly at first, but at a much higher rate for the last ∼ 10 Myr. We provide rough estimates of the star formation rate for the main ρ Ophiuchi molecular cloud complex.

Accepted by MNRAS

A search for precursors of ultracompact HII regions in a sample of luminous IRAS sources. II: VLA observations.

Sergio Molinari[1,2], Jan Brand[1], Riccardo Cesaroni[3], Francesco Palla[3] and Giorgio Palumbo[4]

[1] Istituto di Radioastronomia-CNR, Via Gobetti 101, 40129 Bologna, Italy
[2] IPAC/Caltech, Mail Stop 100-22, Pasadena CA 91125, USA
[3] Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy
[4] Università degli Studi di Bologna, Dipartimento di Astronomia, Via Zamboni 33, I-40126 Bologna, Italy

E-mail contact: molinari@ipac.caltech.edu

We have used the Very Large Array (VLA) to search for radio continuum emission towards a sample of 67 IRAS sources selected from a previous study. All observed sources are associated with high density molecular gas, exhibit an infrared spectral energy distribution characteristic of very cold young stellar objects and many of them are associated with H_2O masers. The observed sample is divided into two groups of sources: *High*, with IRAS spectral energy distributions resembling those of ultracompact HII regions, and *Low*, for which previously collected evidence suggests that they may contain a higher fraction of protostellar objects than the *High* group; such objects might not have started hydrogen burning yet.

Radio continuum emission was detected towards 37 sources (55%), although only in 22 cases an association with the IRAS source is established. Of the latter, 9 (24%) objects belong to the *Low* type and 13 (43%) to the *High* type. Thus, we find that 76% of *Low* and 57% of *High* sources are not associated with a radio counterpart. Because the majority of the sources have luminosities above ∼ 10^4 $L_\odot$, corresponding to central stars of spectral type between B2 and O7, the lack of radio emission is interpreted as being due to the action of accreting matter that chokes off the

expansion of the ionised gas. We show that this requires only moderate mass accretion rates, below $\sim 10^{-4}$ $M_\odot$ yr^{-1}. Alternatively, dust absorption can also effectively absorb UV photons and the gas column density implied by our observations indicates values in excess of 10^{22} cm^{-2}.

The physical properties of IRAS sources with associated radio counterpart derived from the present observations do not distinguish between *High* and *Low* sources. These sources are likely to be ZAMS stars with variable amounts of dust within the ionised region which acts as UV field absorber. The large majority of detected sources (75%) have spherical or unresolved morphology, while 15% are irregular or multiply peaked and only 10% have a core-halo structure. These results agree with the known properties of ultracompact HII regions, even though the average luminosity of the present sample is an order of magnitude lower than that in previous studies.

Accepted by A&A

ISOCAM Molecular Hydrogen Images of the Cep E Outflow

Alberto Noriega-Crespo[1], Peter M. Garnavich[2], & Sergio Molinari[1]

[1] Infrared Processing and Analysis Center, California Institute of Technology-JPL, Pasadena, CA 91125, USA
[2] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

E-mail contact: alberto@ipac.caltech.edu

The physical characteristics of Cepheus E (Cep E) 'embedded' outflow are analyzed using ISOCAM images in the v=0-0 S(5) 6.91 μm and S(3) 9.66 μm molecular hydrogen lines. We find that the morphology of the Cep E outflow in the ground vibrational H_2 lines is similar to that of the near infrared v=1-0 2.12 μm line. At these mid-IR wavelengths, we do not detect the second H_2 outflow which is almost perpendicular to Cep E 2.121 μm flow or traces of H_2 emission along the second ^{12}CO $J = 2 - 1$ outflow at $\sim 52^\circ$ angle, down to a surface brightness of 12 - 46 μJy/arcsec^2.

We do detect at 6.91 μm the likely source of the main H_2 and CO outflows, IRAS 23011+6126, and show that the source is easily seen in all IRAS bands using HiRes images. The source is not detected at 9.66 μm, but we think this agrees with the interstellar extinction curve which has a minimum at ~ 7 μm, but rises a ~ 9.7 μm due to the strong absorption silicate feature, enhanced in this case by a cocoon surrounding the Class 0 object. This idea is supported by our models of the spectral energy distribution (SED) of the central object. The models assume that the main source of opacity is due to bare silicates and our best fit for the SED yields a total mass of envelope of 17 $M_\odot$ and a dust temperature of 18 K.

Accepted by Astron. J. to appear Sept 1998

Methanol Masers as Tracers of Circumstellar Disks

R. P. Norris[1], S. E. Byleveld[1,2], P. J. Diamond[3], S. P. Ellingsen[1,4], R. H. Ferris[1], R. G. Gough[1], M. J. Kesteven[1], P. M. McCulloch[4], C. J. Phillips[1,4], J. E. Reynolds[1], A. K. Tzioumis[1], Y. Takahashi[5], E. R. Troup[1], K. J. Wellington[1]

[1] Australia Telescope National Facility, CSIRO, PO Box 76, Epping, 2121, Australia.
[2] School of Physics, University of Sydney, Sydney, 2006, Australia
[3] National Radio Astronomy Observatory, PO Box 0, Socorro, NM 87801-0387, USA [4] Physics Department, University of Tasmania, GPO Box 252C, Hobart, Tas 7001, Australia [5] Kashima Space Research Centre, CRL, 893-1 Hirai, Kashima, Ibaraki, 314, Japan

E-mail contact: rnorris@atnf.csiro.au

We show that in many methanol maser sources the masers are located in lines, with a velocity gradient along them which suggests that the masers are situated in edge-on circumstellar, or protoplanetary, disks. We present VLBI observations of the methanol maser source G309.92+0.48, in the 12.2 GHz transition, which confirm previous observations that the masers in this source lie along a line. We show that such sources are not only linear in space but, in many cases, also have a linear velocity gradient. We then model these and other data in both the 6.7 GHz and the 12.2 GHz transition from a number of star formation regions, and show that the observed spatial and velocity distribution of methanol masers, and the derived Keplerian masses, are consistent with a circumstellar disk rotating around an OB star. We consider this and other hypotheses, and conclude that about half of these methanol masers are probably located in edge-on circumstellar disks around young stars. This is of particular significance for studies of circumstellar disks

because of the detailed velocity information available from the masers.

Accepted by Ap. J.

http://www.atnf.csiro.au/cgi-bin/preprintselect.pl?filename=1998jun0002

Thermal dust imaging of the cometary HII region NGC 6334 F

Paolo Persi[1], Mauricio Tapia[2], Marcello Felli[3], Pierre Olivier Lagage[4], and Marco Ferrari-Toniolo[1]

[1] Istituto Astrofisica Spaziale, Area di Ricerca Roma-Tor Vergata, Via del Fosso del Cavaliere 00133 Roma, Italy
[2] Instituto de Astronomia, UNAM, Apartado Postal 877, Ensenada, 22830, B.C., Mexico
[3] Osservatorio Astrofisico di Arcetri, Largo E. Fermi , 5. I-50125 Firenze, Italy
[4] CEA/DSM/DAPNIA/, Service d'Astrophysique (URA 2052 du CNRS), CE Saclay, F-91191 Gif-sur-Yvette, France

E-mail contact: persi@saturn.ias.rm.cnr.it

Sub-arcsec images at 3.8 and 11.2 μm of the cometary HII region NGC 6334 F are presented. Only the HII region is detected at 3.8 μm, while three distinct small diameter sources and a diffuse extended emission are found at 11.2 μm. The brightest of the small diameter sources (called MIR 2) is coincident with the HII region. MIR 2 is resolved and shows a cometary shape similar to that observed in the radio continuum. This suggests that warm dust and ionized gas are well mixed in the HII region. The diffuse extended emission is observed in the region where the highest density molecular gas and the central region of the molecular outflow are located. No emission at either wavelength is detected from IRS-I 2, the proposed alternative powering source of the bipolar molecular outflow.

Accepted by Astronomy & Astrophysics

Do Proto-Jovian Planets Drive Outflows?

A. C. Quillen[1] and D. Trilling[2]

[1] Steward Observatory, 933 N. Cherry St., Tucson, AZ 85721, USA
[2] Lunar and Planetary Laboratory, The University of Arizona, Tucson, AZ 85721, USA

E-mail contact: aquillen@as.arizona.edu

We discuss the possibility that gaseous giant planets drive strong outflows during early phases of their formation. We consider the range of parameters appropriate for magneto-centrifugally driven stellar and disk outflow models and find that if the proto-Jovian planet or accretion disk had a magnetic field of > 10 Gauss and moderate mass inflow accretion rates through the disk of less than $\sim 10^{-7} M_J$/yr that it is possible to drive an outflow. Estimates based both on scaling from empirical laws observed in proto-stellar outflows and the magneto-centrifugal disk and stellar+disk wind models suggest that winds with mass outflow rates of order $10^{-8} M_J$/yr and velocities of order ~ 20 km/s could be driven from proto-Jovian planets. Prospects for detection and some implications for the formation of the solar system are briefly discussed.

Accepted by Ap. J.

Infrared excess and molecular clouds: A comparison of new surveys of far-infrared and H I 21-cm emission at high galactic latitudes

William T. Reach[1], William F. Wall[2] and Nils Odegard[3]

[1] Infrared Processing and Analysis Center, California Institute of Technology, MS 100-22, Pasadena, CA 91125, USA
[2] Instituto Nacional de Astrofisica, Optica, y Electonica, A. Postal 51 y 216, Puebla, Puebla, Mexico
[3] Raytheon STX Corporation, 4400 Forbes Blvd., Lanham MD 20706, USA

E-mail contact: reach@ipac.caltech.edu

We have created a map of the large-scale infrared surface brightness in excess of that associated with the atomic interstellar medium, using region-by-region correlations between the far-infrared and 21-cm line surface brightness. Our study updates and extends a previous attempt with the *Infrared Astronomical Satellite* and Berkeley/Parkes H I surveys; in this study we used far-infrared (60–240 μm) data from the *Cosmic Background Explorer* Diffuse Infrared Background Experiment and 21-cm data from the combined Leiden-Dwingeloo and Parkes 21-cm line surveys. Using

the maps of excess infrared emission at 100, 140, and 240 μm, we created an atlas and identified the coherent structures. These infrared excess clouds can be caused both by dust that is warmer than average, or by dust associated with gas other than the atomic interstellar medium. We find very few warm clouds—which are relatively bright at 60 μm—such as the H II region around the high-latitude B-type star α Vir and a new cloud of unknown origin that we name DIR 015+54. Using the ratio of 100 to 240 μm brightness, we find that infrared excess clouds are *cold*. The dust temperature in atomic gas is 19 ± 2 K, while the dust temperature in known high-latitude molecular clouds (all of which have infrared excess) is 15.5 ± 1 K. The dust temperature in those infrared excess clouds that are not known to be associated with molecular clouds (generally because they have never been observed) is 17 ± 2 K, suggesting they are similar to high-latitude molecular clouds. Infrared excess clouds are peaks of column density rather than dust temperature, and their excess infrared emission is likely due to dust associated with molecular gas. For a large region in Ursa Major-Ursa Minor-Camelopardalis, where the CO($1 \rightarrow 0$) line has been surveyed, we correlated the infrared excess CO line integral, allowing us to measure $X = N(\mathrm{H_2})/W(\mathrm{CO}) = (1.3 \pm 0.2) \times 10^{20}$ cm^2 (K km s^{-1})$^{-1}$ for high-latitude molecular clouds. Our measurement of X takes into account the low dust temperature in molecular gas; this correction amounts to a factor of 3.8 increase in the X value that would naïvely be determined using only 100 μm, CO, and H I data. Our value of X is consistent with a recent γ-ray determination for the same region, while it is a factor of about 2 lower than the value determined for the inner galactic plane. The surface mass density of infrared excess clouds is 0.3 $M_\odot$ pc^{-2}. The atlas of infrared excess clouds may be useful as a guide to regions of relatively high interstellar column density, which might extinct light from extragalactic objects at optical to ultraviolet wavelengths and confuse structures in the cosmic background at infrared to microwave wavelengths.

Accepted by Astrophys. J. (scheduled for Nov. 1998)

Herbig-Haro Flows from the L1641-N Embedded Infrared Cluster

Bo Reipurth[1], David Devine[2] and John Bally[1]

[1] CASA, University of Colorado, Boulder, CO 80309, USA

[2] Laboratory for Astronomy and Solar Physics, Code 681 NASA Goddard Space Flight Center Greenbelt, MD 20771, USA

We have discovered a large number of Herbig-Haro flows associated with the embedded infrared cluster surrounding the IRAS source 05338−0624, the driving source of the L1641-N molecular outflow. The best collimated HH flow in the region, HH 303, stretches in two groups of knots along a well defined axis from the VLA source that coincides with the IRAS source. This HH flow is co-axial with the blue northern lobe of the molecular flow. To the NNW of the cluster we find a long series of very large and finely shaped bow shocks, which stretch on a well defined axis away from the cluster. The most distant HH object, HH 310, is 6.3 pc in projection from the center of the cluster, making it the largest HH lobe known from a low mass star. We identify the counterlobe with an already known chain of infrared H_2 emission knots. Additionally, we find two very large fragmented bow shocks, HH 403 and 404, to the NE of and facing away from the cluster. They lie on an axis that passes through the cluster at projected distances of 4.2 pc and 5.4 pc. In the opposite direction to the SW we identify the previously known object HH 127 at a projected distance of 5.2 pc from the cluster and within an angle of 10 degrees of the HH 403/404 axis. HH 127 consists of three faint knots also on a line through the cluster. Precisely south of the VLA source and on the axis of the HH 303 jet we find a large bow shock, HH 61, which is 5.9 pc in projection from the cluster, and which we believe is part of the counterflow to the HH 303 jet. Our CCD images and ^{13}CO maps clearly show that HH 61 and HH 127 are located just beyond the well defined edge of the L1641 cloud, which explains why they are optically visible. Our extensive C^{18}O map of the region shows that the cluster is associated with a prominent cloud core. Our ^{12}CO map reveals, in addition to the known L1641-N outflow, a large pair of compact low velocity outflow lobes, a south-eastern blueshifted lobe and a north-western redshifted lobe, separated by 2.7 pc and centered on the infrared cluster. The numerous outflows in the region is evidence that a large number of the young stars in the loose cluster are presently in active mass losing phases. The L1641-N cluster is clearly the presently most active site of low mass star formation in the L1641 molecular cloud.

Accepted by Astron. J.

Star Formation in Bok Globules: Near-Infrared Survey of a Southern Sky Sample

Nuno C. Santos, João L. Yun, Carlos A. Santos, & Rui G. Marreiros

Departamento de Física, Universidade de Lisboa, Campo Grande, Ed. C1, 1700 Lisboa, Portugal

We performed a near-infrared imaging survey toward 23 Bok globules in the southern sky containing *IRAS* point sources. Visual examination of the images revealed that 15 globules showed evidence of nebular emission or very red stellar objects located at the position of the sources.

Analysis of the near-infrared nebulosities present in the images revealed that: a) these nebulosities generally contain one or more stellar-like sources surrounded by a more or less extended component; b) a couple of possible binaries with separations of about 4 arcsec were found to reside in common infrared nebulosity; c) infrared reflection nebulae, seen at 2.2 μm, are usually associated with class I sources.

The nature of the southern sky sample of Bok globules seems to be similar to that of the northern sample of globules, with similar star formation properties: they tend to form a single or a few stars, and in some cases, they seem to be lodging small aggregates of YSOs.

We confirm that, in general, the value of the 12/25 μm spectral index is a good indicator of the evolutionary stage of a young stellar object. Large negative 12/25 μm indices seem to indicate younger objects deeply embedded in their clouds (by showing nebulosities mostly in the K-band, having associated molecular outflows, and no optical counterparts). As these objects reach later stages of their pre-main sequence evolution (becoming optical visible), their 12/25 μm indices increase and become positive.

Accepted by Astronomical Journal

A copy of this paper is available via the World Wide Web. Connect to http://delphi.cc.fc.ul.pt/papers/southern

Enhanced CO J=2-1/J=1-0 ratio as a marker of supernova remnant - molecular cloud interactions: cases of W44 and IC443

Masumichi Seta[1], Tetsuo Hasegawa[2] , T. M. Dame[3], Seiichi Sakamoto[4], Tomoharu Oka[5], Toshihiro Handa[2], Masahiko Hayashi[6], Jun-Ichi Morino[2], Kazuo Sorai[2] and Kumiko S. Usuda[2]

[1] Communications Research Laboratory, Tokyo 184-8795, Japan
[2] University of Tokyo, Tokyo 181-8588, Japan
[3] Hardard Smithonian Center for Astrophysics, 60 Garden Street, Cambridge, MA02138, USA
[4] Nobeyama Radio Observatory, Nagano 384-1305, Japan
[5] The Institute of Physical and Chemical Research (RIKEN), Saitama 351-0198, Japan
[6] National Astronomical Observatory, Tokyo 181-8588, Japan

E-mail contact: seta@crl.go.jp

We present results of CO (J=2-1) line mapping of molecular clouds in the vicinity of the supernova remnants (SNRs) W44 and IC443. Large areas spanning ≈ 1.5deg x 2deg were observed with the 9' beam of the University of Tokyo-Nobeyama Radio Observatory 60 cm Survey Telescope. We identify six giant molecular clouds (GMCs) with masses (0.3-3)10 5 Mo around W44. Three of them show evidence of interaction with the SNR. In particular, one exhibits a line wing emission and an abrupt velocity shift at the position where the cloud overlaps with the SNR. The CO J=2-1/J=1-0 line intensity ratio significantly exceeds unity (1.3) in the wing. In IC443, a high-velocity line wing emission was detected in CO J=2-1 with our 9' beam. The CO J=2-1/J=1-0 ratio is extremely high (>3) in the wing suggesting that the emission comes from spatially extended optically thin ($\tau \approx 0.1$), dense (n(H2) ≈10 5 cm-3), and warm (≈ 80 K) gas. W44 is established as a good example of a SNR interacting with GMCs, while IC443 is in interaction with a low mass dark cloud. The mass and the kinetic energy of the shocked gas are, respectively, 1x10 3 Mo and 4x10 48 erg in W44, and 70 Mo and 6x10 47 erg in IC443. A very high CO J=2-1/J=1-0 ratio in the line wings of a GMC may be a useful marker of interaction with an SNR. Such a marker would be extremely valuable for determining GMC-SNR associations in the inner Galaxy, where numerous GMCs often lie along the line of sight. Such associations often provide the best means of determining SNR distances.

Accepted by Astrophysical. J.

The quasi Algol GW Ori: nature of the eclipses and estimation of masses of components

V.S. Shevchenko[1], K.N. Grankin[1], S.Yu. Melnikov[1], S.A. Lamzin[2]

[1] Astronomical Institute of Academy of Science of Uzbekistan, Tashkent
[2] Sternberg Astronomical Institute, Moscow V-234, 119899 Russia

E-mail contact: valerys@orc.ru

The regular decrease of GW Ori brightness with a period $P \simeq 242^d$ was found during UBVR-photoelectric photometry. The period is practically equal to that of the GW Ori radial velocity variations discovered by Mathieu et al. (1991,A.J.,101,2184). The duration of the Algol-like dips was $\simeq 0.1P$. They were observed from 1987 to 1992 only and then have disappeared. We suppose that these events occured due to eclipses of the central star by a gas-dust envelope, which filled the Roche lobe of the companion. The brightness of the system during the 1987-1992 period has been decreased at $\simeq 0.1^m$ due to accretion from the flat circumbinary disc. Parameters of the GW Ori components were estimated within the frame of this hypothesis: $M = 3.3\,M_\odot$, $R = 7.5\,R_\odot$, $T_{ef} = 5600$ K – for the primary and $M = 0.3\,M_\odot$, $R < R_\odot$ – for the secondary. The inclination angle of the system $i \geq 83^o$.

Accepted by Astronomy Letters

The Search for Rotational Modulation of T Tauri Stars in the Ophiuchus Dark Clouds

V. S. Shevchenko[1] and W. Herbst[2]

[1] Astronomical Institute of the Uzbek Acad. Sci., Tashkent, Uzbekistan, 700052
[2] Astronomy Department, Wesleyan University, Middletown, CT 06459, USA

E-mail contact: wherbst@wesleyan.edu

We report some results of a long-term photometric program called ROTOR, being carried out at Maidanak Observatory in the Republic of Uzbekistan. The goal of the program is to search for periodic components in the light of T Tauri stars (TTS), Herbig Ae/Be stars (HAEBE), FUOrs and related objects. In this paper we analyze results obtained for TTS in the vicinity of the ρ Oph dark clouds obtained between 1986 and 1993. Our sample includes 6 weak-emission TTS (WTTS) and 11 classical TTS (CTTS). All of the WTTS investigated have significant photometric periods which are attributed to spottedness of the stellar photospheres. Two of them, SR 9 and SR 12, maintained stable periods and phases during the entire span of observation. The periods are between 1 and 4 days, except for SR 9, which has a period of 6.53 days; its relatively large Hα equivalent width (for a WTTS) also suggests it may be a transition object between the WTTS and CTTS. Among the CTTS in our sample, we found only three stars with definite periods, two of which were longer than 8 days. Generally speaking, therefore, our observations are in accordance with the canonical view of WTTS and CTTS, in which stars with more active accretion disks spin slower due to disk locking and show greater irregular variations due to accretion hot spots. The exception is V895 Sco (Haro 1 - 1) which seems to be a typical CTTS with a rotation period of less than 4 days. The stability of the periods and epochs of minima of some or most WTTS is noted and discussed.

Accepted by Astron. J.

An Edge-on Circumstellar Disk in the Young Binary System HK Tauri

Karl R. Stapelfeldt[1], John E. Krist[2], François Ménard[3], Jérôme Bouvier[3], Deborah L. Padgett[4], and Christopher J. Burrows[2]

[1] MS 183-900 Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena CA 91109 USA
[2] Space Telescope Science Institute, Baltimore, MD 21218 USA
[3] Laboratoire d'Astrophysique, Observatoire de Grenoble, Université Joseph Fourier, BP 53, 38041 Grenoble Cedex 9, France
[4] IPAC, Mail Stop 100-22, California Institute of Technology, Pasadena CA 91125 USA

E-mail contact: krs@wfpc2-mail.jpl.nasa.gov

Hubble Space Telescope images of HK Tauri reveal that the companion star in this 2.4″ (340 AU) pre-main sequence binary system is an entirely nebulous object at visual wavelengths. HK Tau/c appears as two elongated reflection nebulosities separated by a dark lane. Near-infrared adaptive optics observations made at the Canada-France-Hawaii

Telescope show a similar morphology, and no directly visible star at $\lambda \leq 2.2$ μm. HK Tau/c is strikingly similar to scattered light models of an optically thick circumstellar disk seen close to edge-on, and to the HST images of HH 30 (Burrows *et al.* 1996, Ap.J. 473 437). HK Tau/c is therefore the first disk to be clearly resolved around an individual star in a young binary system.

The disk properties have been constrained by fitting model reflection nebulae to the HST images. The disk has a radius of 105 AU, inclination of about 5°, scale height of 3.8 AU at $r = 50$ AU, and is flared. The absence of a point source in the near-IR requires $A_V > 50$ mag toward the unseen central star. The thickness of the dark lane establishes a disk mass near 10^{-4} $M_\odot$ (~ 0.1 $M_{\rm Jupiter}$) of dust and gas, if the dust grains have interstellar properties and remain fully mixed vertically. With the observed disk radius equal to only 1/3 the projected separation of the binary, there is a strong possibility that tidal truncation of the circumsecondary disk has occurred in this system.

Accepted by Astrophysical Journal Letters

A search for clustering around Herbig Ae/Be stars II. Atlas of the observed sources

Leonardo Testi[1], Francesco Palla[2] and Antonella Natta[2]

[1] Division of Physics, Mathematics and Astronomy, California Institute of Technology, MS 105-24, Pasadena CA 91125, USA
[2] Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy

E-mail contact: lt@astro.caltech.edu

We present large field infrared images of a sample of 45 Herbig Ae/Be stars. Stellar parameters, such as age and mass, have been derived for all of them in a consistent way. The images have been used to identify stellar groups or clusters associated with the Herbig Ae/Be star. The results presented in this paper form the database for a study of clustering around intermediate mass stars (Testi et al. 1998).

Accepted by Astronomy & Astrophysics Supplement

Preprints available at http://astro.caltech.edu/~lt/preprints/preprints.html

[CII] 158 and [OI] 63 μm ISO-Observations of L1457

Ralf Timmermann[1], Benedikt Köster[1], and Jürgen Stutzki[1]

[1] Universität Köln, I. Physikalisches Institut, Zülpicher Straße 77, 50937 Köln, Germany

E-mail contact: timmer@ph1.uni-koeln.de

We report here the results of [CII] 158 and [OI] 63 μm fine-structure line observations along two cuts across a molecular clump of L1457 (MBM 12) carried out with ISO-LWS. [CII] emission was detected at all positions observed. It can be assigned to the cooling of the diffuse atomic interstellar medium. We observed excess [CII] emission from the dense clumpy molecular component. It is likely to originate from molecular gas that is irradiated by an interstellar FUV-radiation field of order $\chi = (1-2)\chi_0$. Using PDR models for a spherical symmetry we find the molecular gas of L1457 consists of clumps with a density $n_{\rm H} \sim 10^5$ cm^{-3}. Their masses range between 10^{-4} and 10^{-3} $M_\odot$ consistent with the clump distribution derived from high resolution CO observations. [OI] 63 μm emission was not detected toward L1457.

Accepted by A&A Letters

Radiative Transfer Modelling of the Accretion Flow onto a Star-Forming Core in W51

Lisa M. Young[1], Eric Keto[2] and Paul T. P. Ho[2]

[1] Astronomy Department, New Mexico State University, Las Cruces, NM 88003 USA
[2] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138 USA

E-mail contact: lyoung@nmsu.edu

We present an analysis of the temperature, density, and velocity of the molecular gas in the star-forming core around W51 e2. A previous paper (Ho and Young 1996) describes the kinematic evidence which implies that the core around e2

is contracting onto a young massive star. The current paper presents a technique for modelling the three-dimensional structure of the core by simulating spectral line images of the source and comparing those images to observed data. The primary conclusions of this work are that the molecular gas in e2 is radially contracting at about 5 km/s and that the temperature and density of the gas decrease outward over 0.15 pc scales. The simple model of the collapse of the singular isothermal sphere for low-mass star formation (Shu 1977) is an inadequate description of this high-mass molecular core; better models have temperature decreasing outward as $r^{-0.6}$, density as r^{-2}, and velocity increasing as $r^{+0.1}$. The core appears to be spherical rather than disk-like at the scale of these observations, 0.3 pc. In this paper we show how a series of models of gradually increasing complexity can be used to investigate the sensitivity of the model to its parameters. Major sources of uncertainty for this method and this dataset are the interdependence of temperature and density and the assumed NH3 abundance.

Accepted by the Astrophysical Journal.

Preprints are available at astro-ph/9806058

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.

Dissertation Abstracts

Low Density Molecular Gas in the Galaxy

Kumiko S. Usuda

Thesis work conducted at: Department of Astronomy, University of Tokyo, JAPAN

Current address: Subaru Telescope, National Astronomical Observatory of Japan, 650 North A'ōhōku Place, Hilo, Hawaii 96720, USA

Electronic mail: kumiko@naoj.org

Ph.D dissertation directed by: Tetsuo Hasegawa

Ph.D degree awarded: December 1997

In this thesis we investigate physical conditions of low density molecular gas in which CO emission becomes weaker. Two approaches are taken. One is an extensive survey of the outer Galaxy in CO(J=2-1) *emission* line with the 60-cm telescopes in both hemispheres, and the other one is an attempt to detect *absorption* lines in [CI] and $C^{18}O$ toward bright continuum background source in millimeter and submillimeter wavelength.

In the emission line studies, we used the 60-cm telescopes which are designed to obtain well-calibrated CO(J=2-1) data in order to compare the line intensities with the CO(J=1-0) data. We take the CO(J=2-1)/CO(J=1-0) intensity ratio, $R_{2-1/1-0}$, which is a good indicator of excitation temperature. The northern survey for the Perseus arm covers the area l = 108°.5 – 155°.0, b = –2°.5 – +2°.5 on a 0°.5 grid with a 30' beam. A total of 1034 points are observed. The southern survey for the Carina arm covers the area l = 293°.0 – 310°.875, b = –1°.125 – +1°.125 on a 0°.125 grid with a 9' beam. A total of 2736 points are observed. Analyses are made in three different scales for the two arms: statistical properties of molecular clouds ($\sim$ 100pc), distribution of molecular and atomic gas along the arms ($\sim$ 1kpc), and radial distributions of molecular gas and $R_{2-1/1-0}$ ($>$ 1kpc, Galactic scale). Our analyses indicate that in the outer Galaxy, (1) Intensity of CO emission per unit mass is lower, (2) The contrast between the compact components (i.e., molecular clouds) and the diffuse components (i.e., intercloud gas) are higher, (3) Fraction of higher ratio gas ($R_{2-1/1-0} \geq 0.7; T_{\rm k} \gtrsim 20{\rm K}, n({\rm H_2}) \gtrsim 1\times10^3{\rm cm^{-3}}$) which comes from compact components is higher, and the contribution of lower ratio gas ($R_{2-1/1-0} < 0.7; T_{\rm k} \gtrsim 10{\rm K}, n({\rm H_2}) < 1\times10^3{\rm cm^{-3}}$) which comes from diffuse component is extremely lower, than those in the inner Galaxy. In the outer Galaxy the CO emission from diffuse component is hardly detected.

This result suggests that there is a possibility that substantial amount of molecular gas resides unexcited in CO lines because of low density. In the absorption line study, we have detected [CI] and $C^{18}O$ lines toward the bright radio continuum sources, Sgr B2(M) and W49A. Towards Sgr B2(M), we observed not only position toward the continuum source (on-continuum position) but also positions adjacent to the continuum source (off-continuum positions). Solving the simultaneous equations for on-continuum and off-continuum positions, we get the optical depths (τ) and excitation temperatures ($T_{\rm ex}$) independently. Column densities of CI and $C^{18}O$ in the 3-kpc arm are N(CI) = (1–7) $\times$ 10^{17} cm^{-2}, and $N(C^{18}O)$ = (3–5) $\times$ 10^{15} cm^{-2}, respectively. The derived H_2 column density for the 3-kpc arm is $N(H_2)$ = (4.0 $\pm$ 1.8) $\times10^{22}$ cm^{-2}. Large Velocity Gradient (LVG) line formation model indicates that absorption lines arise from less dense ($n(H_2) \lesssim 500{\rm cm^{-3}}$) molecular gas. If the molecular gas in the 3-kpc arm were the standard molecular gas commonly detected in CO emission, the derived H_2 column density should correspond to a CO integrated intensity of $\sim10^2$ K km s^{-1} as we estimate with the CO-to-H_2 conversion factor (X factor) for the inner Galaxy. However, the observed CO intensity of the 3-kpc arm is only $\leq$ 7 K km s^{-1}.

Both of the above two approaches point to a possibility that substantial amount of molecular gas resides in the diffuse component. The low density keeps CO unexcited there. This strongly suggests a serious limitation of the use of the X factor; it can very by up to two orders of magnitude in facial value from a component to another. A versatile tool to estimate the amount of the diffuse molecular component needs to be sought.

The molecular environment of low-mass protostars

Michiel Hogerheijde

Thesis work conducted at: Leiden Observatory, The Netherlands

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

Electronic mail: michiel@strw.leidenuniv.nl

Ph.D dissertation directed by: Ewine F. van Dishoeck and Geoffrey A. Blake (Caltech)

Ph.D degree awarded: June 10 1998

Although well understood qualitatively, many important details about the formation of low-mass stars remain ill determined. In this thesis we try to find some answers to questions like: what is the density, temperature, and velocity distribution in the envelopes around embedded young stellar objects (YSOs)? What is the role of rotation and magnetic fields? At what stage do circumstellar disks form, and what is their evolution? What is the influence of the object's mass, multiplicity, outflow, and star-forming environment?

This thesis investigates (sub) millimeter molecular-line and dust-continuum observations of 13 YSOs: 9 class I objects in Taurus ($d \approx 140$ pc) and 4 more deeply embedded, and possibly more massive, class 0 sources in Serpens ($d \approx 400$ pc). Whereas the Taurus region is prototypical of the isolated mode of star formation, Serpens is forming a dense cluster of stars. Single-dish observations observations were obtained with the James Clerk Maxwell Telescope, the Caltech Submillimeter Observatory, and the IRAM 30m telescope of low- and mid-J lines of CO, HCO^+, HCN, and isotopes. These data are complemented by aperture synthesis observations from the Owens Valley Millimeter Array of HCO^+, HCN, ^{13}CO, and $C^{18}O$ 1–0. The latter data also include continuum measurements at 3.4–1.3 mm. Together, our data set traces densities of 10^4–10^7 cm^{-3}, temperatures of 10–100 K, and scales of a few hundred to 10,000 AU, typical of YSO envelopes. An important step in the analysis is formed by Monte Carlo calculations of the radiative transfer and molecular excitation employing axisymmetric source models.

The main conclusions of this thesis are:

1. Throughout the embedded class 0 and I phases single-dish molecular line observations trace the envelope density structure, especially in HCO^+ 3–2 and 4–3, which exclusively sample dense envelope gas. The class 0 envelopes are sufficiently massive that interferometric observations of spatial resolved continuum emission provide additional, accurate constraints on the density distribution.

2. The inside-out collapse model formulated by Shu (1977) describes well the observed molecular lines on scales of a few thousand AU as sampled by single-dish instruments. The resolved continuum emission from class 0 envelopes indicates a radial power law for the density with slope -2.0 ± 0.5, consistent with the molecular line fits. Whereas the models invariably predict "infall asymmetry" for optically thick molecular lines, the observations only show these unambiguously in lines like HCO^+ 3–2 and 4–3, which exclusively sample the envelopes.

3. On smaller scales of 700–1500 AU as sampled by the interferometer, the envelopes deviate from spherical symmetry, suggesting flattening and rotation. Collapse models including these effects reproduce the observed characteristics, although a more detailed description is warranted.

4. Two-thirds of the class I Taurus sources are surrounded by a circumstellar disk, as evidenced by the presence of unresolved ($< 3''$) continuum emission. Their similar fluxes compared to class II sources suggest that there is little disk evolution from the embedded to the early T Tauri phases. The detection of disks around the more embedded class 0 objects is prohibited by their massive, centrally concentrated envelopes which dominate the unresolved flux.

5. Sub-arcsecond resolution observations of the young binary system T Tau reveal that only the optical star T Tau N is surrounded by a sizeable disk. Strong upper limits on any circumstellar material are obtained for the infrared star T Tau S. It is proposed that the embedded appearance of this source may be due to T Tau N's disk, if this obscures T Tau S as seen from Earth.

6. The observed correlation between envelope mass, disk continuum flux, and outflow strength supports the notion that outflows are driven by disk accretion, and suggests that the infall rate increases with envelope mass. In lines of HCO^+ the interferometer traces the interaction of the outflow with the surrounding envelope, which can be successfully modeled as a mixing layer.

For a postscript version of this thesis, see `http://www.strw.leidenuniv.nl/~michiel/publications.html`

Meetings

CALL FOR REGISTRATION

CITA Workshop on Gravitational Collapse Leading to Star Formation

4–6 October, 1998

Hosted by the Canadian Institute for Theoretical Astrophysics Toronto, Canada.

The time is right to have a focused workshop on the important problem of gravitational collapse. Recent advances in observational capacity mean that we are now detecting infall signatures and the earliest protostellar phases. This comes on the heels of increasingly sophisticated theoretical models for collapse. We intend to bring together the leading researchers in the field. Is there a consensus on how stars form? What are the important unresolved issues?

Topics to be covered include:

structure of dense cores, infall signatures,
mass accretion onto protostars, hydrodynamic collapse,
collapse in the presence of magnetic fields,
models for multiple star formation,
the link between collapse and the formation of disks and outflows,
the role of waves/turbulence in support and collapse.

A preliminary list of speakers includes:
P. Andre* (Saclay), A. Boss (Carnegie), N. Evans (Texas), T. Hanawa (Nagoya), R. Henriksen (Queens), R. Klein (Berkeley), R. Larson (Yale), T. Mouschovias* (Illinois), P. Myers (CfA), F. Nakamura (Niigata), N. Ohashi (IOAA, Taipei), R. Pudritz (McMaster), F. Shu (Berkeley), D. Ward-Thompson* (Cardiff). (Note: * indicates tentative).

Organizers:
Shantanu Basu (CITA), Doug Johnstone (CITA)

Please visit our conference website for the REGISTRATION form and for information on travel and accommodation. The deadline for registration is July 15, 1998; however, we will stop accepting registrations when we reach forty participants. Therefore, we recommend that you register early.

http://www.cita.utoronto.ca/∼basu/collapse/

or e-mail basu@cita.utoronto.ca or johnstone@cita.utoronto.ca