THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

No. 14 — 6 Oct 1993 Editor: Bo Reipurth (reipurth@eso.org)

Abstracts of recently accepted papers

High-velocity hot ammonia in bipolar outflows

R.Bachiller, J. Martın-Pintado, and A. Fuente

Centro Astronómico de Yebes (IGN). Apartado 148, E-19080 Guadalajara, Spain

We have detected high-velocity ammonia emission associated with four bipolar molecular outflows excited by young stars (L1157, L1448, IRAS3282, and NGC2071). The high-velocity emission is more prominent in the (3,3) line, although it is also detected in the (1,1), (2,2) and (4,4) lines. We deduce that the accelerated gas is heated to more than 50- 100 K, i.e. a factor of 3- 7 over the ambient temperatures (which are in the range 12- 26 K). Such temperatures, when taken into account in the analysis of previous SiO observations, confirm that the shocked material is rather dense ($n(H_2) \geq 10^5$ cm^{-3}). The NH_3 (3,3) lines, similarly to the SiO emission, arise from shocked material placed along highly-collimated jets or at the lobe ends, and are thus better understood in the frame of jet-driven models for bipolar outflows.

Accepted by Astrophys. J. Letters

Molecular Hydrogen in the IRAS03282+3035 Stellar Jet

John Bally[1], David Devine[1], Mark Hereld [2], and Bernard J. Rauscher[2]

[1] Department of Astrophysical, Planetary, and Atmospheric Sciences and Center for Astrophysics and Space Astronomy, Campus Box 389, University of Colorado, Boulder, CO 80309, USA
(bally@janos.colorado.edu, devine@casa.colorado.edu)

[2] Department of Astronomy and Astrophysics, The University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA
(hereld@oddjob.uchicago.edu, bjr@oddjob.uchicago.edu)

We detected shock excited 2.122 μm molecular hydrogen from the blueshifted lobe of the highly collimated CO outflow associated with the young stellar object IRAS03282+3035 in the Perseus molecular cloud. The H_2 emission has a peak surface brightness of 5×10^{-4} ergs s^{-1} cm^{-2} sr^{-1}, making this one of the brightest shock excited molecular hydrogen sources associated with a low-mass young stellar object. The emission has knotty structure with faint tails lying parallel to the mean outflow axis. These knots coincide with molecular "bullets" B3 and B4 located near the end of the highest velocity CO emitting component and may be bow shocks where a fast jet interacts with the surrounding medium. The bulk of the lower velocity CO emission is located downwind from the H_2 emission zone. We discuss the complex morphology in the context of jet-driven CO outflow models, and argue that the H_2 emission delineates regions where CO bearing gas is entrained in the flow and accelerated, thereby producing the more slowly moving CO outflow. The H_2 luminosity radiated by this outflow is about 10% of the bolometric luminosity of the central driving source. This is the largest ratio of $L(H_2)/L_{bol}$ for any known young stellar object.

Accepted by The Astrophysical Journal (Letters)

IRAS sources beyond the solar circle. IV. Maps of far-outer Galaxy molecular clouds.

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

[1] Istituto di Radioastronomia C.N.R., Via Irnerio 46, I-40126 Bologna, Italy
[2] Osservatorio Astrofisico di Arcetri, Florence, Italy
[3] I. Physikalisches Institut, Zülpicher Strasse 77, D-50937 Köln, Germany

We present the results of ^{12}CO(J=1–0) observations of molecular clouds located in the far-outer Galaxy. All clouds have distances from the galactic center R$\geq$16 kpc, and all contain at least one IRAS point source with a FIR spectral distribution typical of star forming regions.
The data are presented in the form of maps of integrated intensity and peak temperature, and we show channel maps where relevant. For each cloud the mass is calculated both using a constant ratio (X) between $\int T_{mb}(CO)dV$ and $N(H_2)$, and according to the virial theorem. The equivalent radius of each cloud is determined in two ways: from the area, and from an intensity-weighted average of the detected positions. Additional observations of ^{12}CO(J=2–1), ^{12}CO(J=3–2), ^{13}CO(J=1–0), and ^{13}CO(J=2–1), mostly at the IRAS position, are also presented. A detailed analysis and discussion of the results, as well as a comparison with inner Galaxy clouds, will be given in a following paper.

Accepted by Astron. Astroph. Suppl.

H II regions and IRAS PSC sources: the reliability of the association

Claudio Codella[1], Marcello Felli[2], Vincenzo Natale[3]

[1] Dipartimento di Astronomia e Scienza dello Spazio, Università di Firenze, Largo E. Fermi 5, 50125 Firenze, Italy
[2] Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy
[3] C.N.R., C.A.I.S.M.I., Largo E. Fermi 5, 50125, Firenze, Italy

The IRAS Point Source Catalogue has been compared with a catalogue of 462 (diffuse) H II regions detected in hydrogen radio recombination lines. To distinguish the true IRAS counterpart of the H II region from chance coincidences the distribution of offset and the position in colour-colour plots as a function of F(60 μm) are investigated. It is found that sources with F(60 μm) $<$ 100 Jy have a high probability of being chance coincidences. The far infrared properties of the H II regions are investigated for a subsample of 252 IRAS PSC sources which have a high ($>$ 80%) probability of being true coincidences. The majority satisfy the Wood and Churchwell colour criteria which identify ultracompact H II regions; therefore, these criteria select ultracompact as well as more diffuse H II regions, or, alternatively, diffuse H II and ultracompact H II regions may often be mixed, as predicted by the sequential star formation theory.

The luminosity of a single star required to produce the observed H II line emission correlates very well with the far infrared luminosity and is, on the average, higher than the observed value. Consequently, the stars ionizing the extended HII regions can account for the bulk of the observed FIR emission and no contribution from lower mass stars of the cluster is necessary.

Accepted by Astronomy and Astrophysics

Star formation at compressed interfaces in turbulent self-gravitating clouds

Bruce G. Elmegreen

IBM T.J. Watson Research Center, PO Box 218 Yorktown Heights NY, 10598 USA

Supersonic turbulence in both self-gravitating and diffuse clouds can produce self-similar, hierarchical density structures and broad line-wings on a wide range of scales, making these two cloud types look similar and giving the clumps in each the same scaling laws. We show that the dense compressed regions that form between converging turbulent flows should collapse to form dense cores and ultimately stars in self-gravitating clouds, whereas they only disperse and reform intermittently in diffuse clouds. Star formation in turbulence-compressed regions should be as hierarchical as the turbulence, leading to clusters and multiple star systems instead of single stars; some binary stars may form by gravitational capture of stars in nearby turbulent clumps. Reasonable mass functions for clumps and stars are estimated from the theory. The slope of the initial stellar mass function is steeper than that for the clumps because of the increasing lifetime for clumps with larger mass.

Accepted by ApJ Letters

A chemical study of the photodissociation region NGC 7023

A. Fuente, J. Martın-Pintado, J. Cernicharo, R. Bachiller

Centro Astronómico de Yebes (IGN), Apdo. 148, E-19080 Guadalajara, Spain

To investigate the effects of the UV radiation on the chemistry of nitrogenated molecules in molecular clouds, we have carried out an observational study of the photodissociation region (PDR) associated with the reflection nebula NGC 7023. We mapped a region of 3 arcmin×3 arcmin over the PDR in millimeter transitions of ^{12}CO, ^{13}CO, $C^{18}O$, HCO^+, HCN, HNC and N_2H^+. Spectra of CS, CN and C_2H and of the rarer isotopic species $H^{13}CO^+$, $H^{13}CN$, and $HN^{13}C$, were also obtained at selected positions. We find evidences of selective photodissociation in the estimated $^{13}CO/C^{18}O$ ratio. Futhermore, all molecular abundances, except those of CN and perhaps C_2H, decrease towards the star, and significant gradients in the values of some molecular abundance ratios (the HNC/HCN ratio decreases by a factor of 5, the N_2H^+/HCO^+ ratio decreases by a factor of 12, the CN/HCN ratio increases by a factor of 8 and the (CN+HCN+HNC)/NH_3 ratio increases by a factor of 30 towards the star position) reveal the existence of important chemical changes in this direction.

Chemical equilibrium model calculations have been also carried out in order to interpret the observed behavior. Our results show that the variations found in molecular abundances cannot be explained by the kinetic temperature and/or the hydrogen density gradients measured in this region. The observed behavior is well explained by the influence of the stellar UV radiation on the chemistry of the molecular gas if the emission arises in a region at a visual extinction between 6 and 10 mag from the star. Molecular destruction in this region ($A_v \sim 6$ mag) is due mainly to reactions with H^+, C, H, C^+, O, and to electronic recombination. The CN/HCN ratio is suggested as a tracer of enhanced UV fields.

Accepted by Astron. Astrophys.

Are Wide Pre-Main-Sequence Binaries Coeval?

Patrick Hartigan, Karen Strom, and Steve Strom

Five College Astronomy Department, University of Massachusetts, Amherst, MA 01003 USA

We have observed a sample of 39 wide (projected separations 400 AU – 6000 AU) pre-main-sequence binary pairs spectroscopically and with optical and near-infrared images. The observations enable us to place 26 of the pairs in an HR-diagram and to determine masses and ages of the primary and secondary according to three sets of pre-main-sequence evolutionary tracks. In two-thirds of the cases the primary and secondary lie along the same isochrone to within the observational errors. However, real age differences appear for about one-third of our sample pairs – there is no set of non-intersecting theoretical isochrones that can make the primary and secondary have the same age for all pairs in our sample. In the cases where there are significant age differences between the component stars, the less massive star is usually younger than the more massive star. There is no correlation of the age differences with the presence or absence of accretion disks around the young stars. Hence, while disk accretion may affect the evolutionary tracks of pre-main-sequence stars HR-diagram, we see no clear evidence of this effect among the pairs in our sample. The age differences also do not depend systematically on the apparent separation, the mass ratio, or the ages of the stars.

Accepted by the Astrophysical Journal

High-Resolution Millimetre and Submillimetre Continuum Observations of M17SW – II. Identification of Embedded Sources Associated with H_2O masers

M.P. Hobson[1], R. Padman[1], P.F. Scott[1], R.M. Prestage[2] and D. Ward-Thompson[1,3]

[1] Mullard Radio Astronomy Observatory, Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, U.K.
[2] Joint Astronomy Center, 660 North A'ohoku Place, Hilo, Hawaii 96720, U.S.A.
[3] Royal Observatory, Blackford Hill, Edinburgh EH9 3HJ, U.K.

The M17SW molecular cloud core has been mapped in continuum emission at 450, 600, 800, 1100 and 1300 μm, using the James Clerk Maxwell Telescope, with an angular resolution of 8 arcsec for the shortest wavelength. The 450- and 600-μm maps, in particular, show the dust emission to be highly clumped; these clumps are, in some cases, identified with those seen in previous optically thin line observations. The continuum observations are consistent

with a single greybody at a temperature of 30 K, and suggest masses of 7600 and 1300 $M_\odot$ for the entire M17SW region and the northern condensation respectively; the corresponding total integrated luminosities for each region are 2.4×10^5 and 4.2×10^4 $L_\odot$. Using an analytical inversion technique, however, which allows for a continuous range of dust temperatures, we find a mass-weighted average temperature of ≈18 K, and masses for M17SW and the northern condensation alone of 1.6×10^4 and 2000 $M_\odot$ respectively. The flux from the northern condensation is dominated by three main components, each of which lies within a few arcsec of an H_2O maser. All these objects have central densities greater than the Jeans critical density, and have masses in the range 300 to 450 $M_\odot$ with luminosities of 8000 to 12 000 $L_\odot$; these values are consistent with them containing very deeply embedded young stellar objects of mass ∼ 10 $M_\odot$.

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

A Maximum Entropy Method for Reconstructing Dust Temperature Distributions from Millimetre and Submillimetre Fluxes

M.P. Hobson and R. Padman

Mullard Radio Astronomy Observatory, Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, U.K.

We present a numerical, maximum entropy technique for reconstructing the distribution of dust mass as a function of temperature from a set of thermal continuum fluxes. The particular formulation used can accommodate an arbitrary wavelength dependence of dust emissivity, but does requires the emission to be optically thin. The dust emission spectrum of the M17SW molecular cloud is analysed, assuming a dust emissivity $\kappa_\nu \propto \nu^2$, and the resulting dust temperature distribution is found to differ markedly from that predicted by the analytical inversion technique of Xie et al. (1993).

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

A Deeply Embedded Companion to LkHα198

P.O. Lagage[1], G. Olofsson[2], S. Cabrit[3], C.J. Cesarsky[1], L. Nordh[2] and J.M. Rodriguez Espinosa[4]

[1] Service d'Astrophysique, C.E. Saclay, F-91191 Gif-sur-Yvette, France. e-mail: lagage@sapvxg. saclay. fr
[2] Stockholms Observatorium, S-13336 Saltsjöbaden, Sweden
[3] Observatoire de Grenoble, BB 53X, F-38041 Grenoble Cedex, France
[4] Instituto de Astrofisica de Canarias, E-38200 La Laguna, Tenerife, Spain

The region around the Herbig Ae/Be star LkHα198 was imaged with the 10μm CAMIRAS camera mounted on the Canada France Hawaii Telescope and on the Nordic Optical Telescope. We discovered, 6" north of LkHα198, a deeply embedded ($A_V > 35$) source, which may play an important role in the region, as indicated by its observed flux (∼ 40% of LkHα198 at 12.3μm) and its position on the optical images (on the axis of the elliptical optical nebula). It is quite likely that it is in fact the new embedded source, and not LkHα198, which drives the CO molecular outflow seen in this region. At the resolution of our observations (FWHM = 1.3"), LkHα198 appears point-like, so that the mid infrared excess from this object cannot be due to an extended envelope of transiently heated small grains.

Accepted by Ap. J. Letters

The young stellar population associated with the HII region NGC 3576

P. Persi[1], M. Roth[2], M. Tapia[3], M. Ferrari-Toniolo[1] and A.R. Marenzi[1]

[1] Istituto Astrofisica Spaziale, CNR, Frascati, Italy
[2] Las Campanas Observatory, Carnegie Institution of Washington, La Serena, Chile
[3] Instituto de Astronomía, UNAM, Ensenada, México

JHK images and photometry of sources associated with the HII region NGC 3576 are presented together with an $8 - 13\mu$m CVF spectrum of the most conspicuous source in the region, Irs 1. A total of 135 sources were detected in K in the surveyed area of 340×340 square arc seconds. From the spatial distribution and photometry we deduced the presence of a very young massive star cluster deeply embedded in the molecular cloud. Comparison of the apparent K luminosity distribution of the cluster region with that of surrounding areas, suggests that the cluster contains more

than fifty members brighter than $K \simeq 13$, the majority of which (> 40) show significant IR excess. A steep gradient in the near-infrared colour is seen from the north-east to the south-west of the cluster indicating that the formation of stars started further out of the cloud and as the older population expands, it has progressed to deeper parts into the cloud where the more recent events are taking place. In the core, the star formation efficiency is found to be 0.19. The distance to this cluster is estimated to be 2.4 kpc.

Accepted by Astron. & Astrophys.

Young Stars associated with the Vela Molecular Ridge. I. VMR clouds C and D, Collinder 197 and Vela R2

Bertil Pettersson[1] **and Bo Reipurth**[2]

[1] Astronomiska Observatoriet, Box 515, S-751 20 Uppsala, Sweden
[2] European Southern Observatory, Casilla 19001, Santiago 19, Chile

An objective prism survey for Hα-emission-line stars towards the H II regions RCW 27, 32 and 33 and the northwestern parts of the Vela Molecular Ridge is presented. 278 Hα-emitting objects have been found and their relation to the H II regions and to dark clouds in the area is discussed. We identify what appears to be two new large associations of T Tauri stars, Vela T1 and T2. The relation of low-mass Hα-emission stars with the Vela Molecular Ridge is discussed.

Accepted by Astron.Astrophys.Suppl.Ser.

ROSAT–detection of a giant X-ray flare on LkHα92

Th. Preibisch[1], **H. Zinnecker**[1] **and J.H.M.M. Schmitt**[2]

[1] Institut für Astronomie und Astrophysik der Universität Würzburg, Am Hubland, D–97074 Würzburg, Federal Republic of Germany, Internet: preib@astro.uni-wuerzburg.de, hans@astro.uni-wuerzburg.de
[2] Max-Planck-Institut für Extraterrestrische Physik, D–85748 Garching, Federal Republic of Germany

We report the detection of a giant X-ray flare on the classical T Tauri star LkHα 92 with the ROSAT PSPC. In this flare the PSPC count rate rose by a factor of more than 100 in a time interval of about 2000 sec. Our X-ray observations cover most of the rise phase as well as part of the decay phase of the flare.

We model the X-ray spectra obtained at different flare phases to determine temperature and emission measure of the flaring plasma. Combining the thus derived X-ray luminosity with the observed decay time scale of $\approx$ 7800 sec, we estimate the total energy release of the flare in the ROSAT PSPC band (0.1 – 2.4 keV) to be $\approx 4 \times 10^{36}$ erg, which is more than a factor of 10^4 greater than the energy release in the strongest solar flares and still more than a factor of 100 greater than that in typical flares on T Tauri stars.

Accepted as a Letter in Astronomy and Astrophysics

A Numerical Study of Viscous Flows in α Accretion Disks

Michal Różyczka[1], **Peter Bodenheimer**[2] **and K. R. Bell**[2]

[1] Warsaw University Observatory, Al. Ujazdowskie 4, 00478 Warszawa, Poland
[2] UCO/Lick Observatories, Board of Studies in Astronomy and Astrophysics, University of California, Santa Cruz, CA 95064, USA

Two-dimensional axisymmetric solutions of the equations of hydrodynamics, including radiation transport and local energy generation due to viscosity, are presented for the case of non-self-gravitating protoplanetary disks around young solar-type stars. The parameters that are varied include the accretion rate in the disk, the magnitude of the viscosity parameter α, the boundary conditions, and the initial conditions. In general, for $\alpha > 0.05$ and for distances > 0.5 AU, the flow pattern is found to consist of a radial outflow near the equatorial plane and a radial inflow near the disk surface. Unlike one-dimensional vertical structure models in this regime, the flow is stable to convection, implying a physically inconsistent model in which the convective turbulence required to generate the viscosity is actually not present. Reduction of α to order 10^{-3} is necessary to regain consistency. However, in the warmer regions interior to 0.5 AU, where the opacity rises steeply as a consequence of hydrogen ionization, a physically consistent turbulent flow is found even for $\alpha = 0.05$. Model results are compared with one-dimensional vertical structure calculations.

Accepted by Astrophys. J.

The Kinematics of Molecular Outflows

Steven W. Stahler[1]

[1]Department of Astronomy, U. of California, Berkeley, CA 94720, USA

If molecular outflows represent turbulent material entrained by a central jet, then the surfaces of constant velocity should spread outward from the jet axis. Using the results of CO observations, I propose an empirical velocity distribution of this character. Outflows with this distribution display the well documented "acceleration" phenomenon, *i.e.*, the increase in terminal velocity away from the driving star

Accepted by Astrophys. J.

A Multiwavelength Study of Star Formation in the L1495E Cloud in Taurus

Karen M. Strom[1], **and Stephen E. Strom**[1]

[1] Five College Astronomy Dept., University of Massachusetts, Amherst, Mass. 01003, USA
Electronic Mail: kstrom@hanksville.phast.umass.edu; sstrom@donald.phast.umass.edu

We have carried out a deep (t=30000s) x-ray search of the eastern portion of the L1495 cloud centered on the well known weak line T Tauri star (WTTS) V410 Tau using the ROSAT PSPC. This deep exposure enabled a search for candidate pre-main sequence (PMS) objects in this cloud to a limit ~ 20 times more sensitive than that typical of the fields examined with the *Einstein* searches. Despite assertions that the PMS population in Taurus-Auriga is nearly completely known, this x-ray survey revealed 8 new PMS objects in a region 50' in diameter, as compared to a previously known stellar population of 12 objects, including deeply embedded IRAS sources.

Spectroscopic and photometric observations enable us to place these objects in the HR Diagram. The newly discovered objects are predominantly stars of spectral type M0 and later, and a large fraction (6/8) appear to be surrounded by circumstellar accretion disks as judged by their infrared excess and Hα emission. We combined the data for these x-ray discovered objects with extant and new data for the previously identified PMS stars in this region to examine the history of star formation and the frequency distribution of stellar masses in this cloud.

If the "post ROSAT" population is either complete or representative, we conclude (1) that star formation in L1495 East took place $\sim 1 \times 10^6$ yrs ago and that the spread in ages is small; (2) the frequency distribution of masses, N(M), in this apparently coeval group appears to peak near $\log M = -0.5$ (using masses derived from the recently published PMS tracks of D'Antona & Mazzitelli (1993) and Swenson et al. (1993)) and to decline toward lower masses. The derived N(log M) for L1495E compares well with the IMF derived from studies of stars in the solar neighborhood, a result which suggests that the Taurus-Auriga clouds are currently producing stars whose mass spectrum approximates the time/space averaged IMF for the solar neighborhood.

Accepted by Ap. J.

Shear in the IRAS 03282 outflow

M. Tafalla[1], **R. Bachiller**[2], **J. Martin-Pintado**[2], **M.C.H. Wright**[1]

[1] Astronomy Department and Radio Astronomy Laboratory, Univ. of California at Berkeley (USA)
[2] Centro Astronómico de Yebes (IGN), Apdo. 148, E-19080 Guadalajara, Spain

We have observed with high-resolution the ammonia emission around IRAS03282, a young star with a highly collimated molecular outflow. Our data show the outflow, passing through the core, accelerates the dense gas and produces a shear-like velocity field. The acceleration occurs along the walls of a cavity which the outflow seems to have evacuated.

Accepted by Astrophys. J. Letters

Speckle imaging of T Tauri stars in the L and M near-IR bands

E. Tessier[1], J. Bouvier[1], and F. Lacombe[2]

[1] Observatoire de Grenoble, Université Joseph Fourier, BP 53X, 38041 Grenoble Cedex, France
[2] Observatoire de Paris, Section de Meudon, Place Jules Janssen, F-92195 Meudon Principal Cedex, France

We present the results of speckle observations of 10 classical T Tauri stars (CTTS) in the L' ($3.87\mu m$) and M ($4.8\mu m$) near-IR bands. These wavelengths were selected in order to search for cold companions to CTTS with a strong IR excess. No new companions were found but known close IR companions were measured in L', most of which had previously been detected at K, thus providing the K-L color of each component. No extended structures beyond 15 AU are detected in any of the observed T Tauri stars. The young binary system Z CMa has also been resolved at M but the extended structure reported by Malbet et al. (1993) is not seen in our data to an upper limit in flux ratio of 5%.

Accepted by Astronomy and Astrophysics

A new catalogue of members and candidate members of the Herbig Ae/Be (HAEBE) stellar group

P.S. Thé[1], D. de Winter[1], M.R. Pérez[2]

[1] Astronomical Institute "Anton Pannekoek", University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands. E-mail address: psthe@astro.uva.nl
[2] IUE Observatory-CSC/Code 684.9, NASA-GSFC, Greenbelt, MD 20771, USA.

A new up-to-date catalogue of Herbig Ae/Be (HAEBE) stars and related objects is certainly needed, for both well-seasoned researchers and, in particular, for new investigators starting to study the many interesting astrophysical properties of these very young objects. We present a brief discussion of the current observational characteristics that distinguish this class from their main sequence counterparts. The HAEBE and related stars are listed in five table, containig 287 objects. Table I contains all Ae and Be stars which historically are recognized as true HAEBE stars or potential candidate members. Table II gives the stars of spectral type Fe, and emission line stars with very uncertain or unknown spectral type. In Table III are given all known Extreme Emission Line Objects (EELOs), of which most have not been identified to belong to any specific group. Table IVa and b list other Bep or B[e] stars with strong IR-excess and unknown spectral type. Table V contains the non-emission line possible young objects. Furthermore, Table VI contains 35 stars rejected from former published lists of HAEBE stars. In these table we are including coordinates, spectral types, visual magnitudes, ranges in photometric variability and references of several key publications related to each object. Relevant remarks, such as the presence of a nebula in the vicinity of an object, are also given.

Accepted by Astronomy and Astrophysics Supplement Series

Infrared Spectroscopy and Imaging Polarimetry of the disk around the T Tauri Star RNO 91

David A. Weintraub[1], Stephen C. Tegler[2], Joel H. Kastner[3,4] and Terrence Rettig[2]

[1] Department of Physics & Astronomy, Vanderbilt University, Nashville, TN 37235, USA
[2] Department of Physics, University of Notre Dame, Notre Dame, IN 46556, USA
[3] M.I.T. Haystack Observatory, NEROC, Route 40, Westford, MA 01886, USA
[4] Present address: M.I.T., Center for Space Research, 37-667a, Cambridge, MA 02139, USA

We present 3 to 5 μm spectra and a 2.2 μm polarimetric image of the T Tauri star RNO 91. We report the detection of three absorption bands centered at 3250 cm^{-1} (3.08 μm), 2139 cm^{-1} (4.68 μm), and 2165 cm^{-1} (4.62 μm) in spectra of RNO 91. These features are due to frozen H_2O, CO and possibly XCN along the line of sight toward RNO 91. Our 2187 to 2107 cm^{-1} spectrum of RNO 90, the only other T Tauri star in the dark cloud L43, does not show the CO or XCN absorption bands. By comparing our observed polarimetric image with modeled images of scattered light from bipolar nebulae or circumstellar disks as well as with the known morphology of the RNO 91 bipolar outflow, we demonstrate that the reflection nebulosity seen in the near-infrared is most likely a circumstellar disklike structure with a radius of $\sim$ 1700 AU. The location of both RNO 90 and RNO 91 in front of or near the front of L43 suggests that the intracloud optical depths toward both stars are small and, therefore, that the frozen H_2O, CO and XCN

molecules are located on grains in circumstellar material around RNO 91 at distances from the central star of perhaps 10 to 1700 AU. This frozen material may represent precometary grains orbiting RNO 91.

Accepted by Ap. J.

Maps of 92 GHz Methyl Cyanide Emission in Orion-KL

D.J. Wilner, M.C.H. Wright, and R.L. Plambeck

Radio Astronomy Laboratory, University of California, Berkeley, CA 94720
wilner@ucbast.berkeley.edu

We present $4'' - 6''$ images of the methyl cyanide (CH_3CN) $J = 5_K - 4_K$ lines toward the Orion-KL region obtained with the Hat Creek millimeter interferometer. The morphology of the low excitation lines closely follows the distribution of dust emission, while the higher excitation lines are confined to a $\sim 10''$ region near IRc2. Methyl cyanide emission is found associated with all of the previously recognized source substructures, including the hot core, CS1 condensation ("10 kms^{-1} feature"), compact ridge ("8 kms^{-1} feature"), western clump, extended ridge, and northwest filament. Methyl Cyanide, like other symmetric top molecules, makes an excellent thermometer. Statistical equilibrium calculations constrain the temperature of the CS1 condensation to the range $52 - 83$ K and the temperature of the southern ridge to the range $120 - 170$ K. Dynamical interactions with the IRc2 outflow likely contribute to heating these regions. Much higher temperatures, > 250 K, are indicated for the hot core, where the CH_3CN abundance is enhanced by at least two orders of magnitude, presumably due to grain chemistry.

Accepted by Ap.J.

A Well-Shaped Bipolar Outflow Shell in Mon R2

Taoling Xie[1],[2], Paul F. Goldsmith[1],[3] and Nimesh Patel[1]

[1] Five College Radio Astronomy Observatory, Department of Physics and Astronomy, University of Massachusetts, Amherst, MA 01003, USA
[2] Jet Propulsion Lab, MS 169-506, California Institute of Technology, Pasadena, CA 91109, USA
Tel:(818)354-7895 FAX:(818)354-8895 Email: tao@koala.jpl.nasa.gov
[3] National Astronomy and Ionosphere Center, Department of Astronomy, Cornell University, Ithaca, NY 14853-6801, USA

We report some results of a study of the massive bipolar outflow in the central region of the giant molecular cloud Monoceros R2. We find in our *CO* $J = 1 - 0$ maps an "eggplant-shaped", thin bipolar outflow shell which outlines the extended blue lobe of the bipolar outflow. The projected length and width of the shell are about 5.3 pc and 2.7 pc respectively, and the averaged projected thickness of the shell is ~ 0.3 pc. The outflow shell's symmetry axis is inclined by $\sim 70°$ with respect to the line of sight. We make a quantitative comparison of our results with the Shu *et al.* outflow model incorporating a radially directed wind, and find that this simple model naturally explains the shape of the observed shell. Although the model predicts with reasonable parameters too much mass at the smallest polar angles, as previously pointed out by Masson & Chernin, it provides a reasonable fit to the data at larger polar angles. We feel that it is possible that this discrepancy is a result of density inhomogeneities on different scales which are not considered in the current model.

Accepted by Astrophys. J. Letters

Dissertation Abstracts

Star formation: variability of pre-main sequence objects

Matilde Fernández

Thesis work conducted at: Observatorio Astronómico de Madrid & Universidad Autónoma de Madrid

Current address: Dpto. Física Teórica, C-XI, Universidad Autónoma de Madrid, Cantoblanco 28049 Madrid, Spain

Address as of 3 January 1994: Apartado 70-264, Ciudad Universitaria, 04510 México D.F., México

Electronic mail: matilde@astro1.ft.uam.es

Ph.D dissertation directed by: Carlos Eiroa

Ph.D degree awarded: September 1993

We have studied the optical continuum variability of 24 pre-main sequence objects and its relation to the accretion and mass loss processes.

We have selected a sample of 24 low and intermediate mass pre-main sequence objects (classical T Tauri stars and Ae/Be Herbig stars), some of which show evidences of high mass loss rate. In order to study the optical continuum variability we carried out photometric observations, UBV(RI)$_c$ system, for four years (July 1988 - August 1992). We have also carried out spectroscopic observations of the H$_\alpha$ region (July 1989 - August 1990).

The variable stars of our sample show an irregular continuum variability. This irregular behaviour is not an observational bias since the temporal interval between consecutive measurements is shorter than the time scale of the variations. We have proved that, despite this irregular nature we can get some conclusions on the origin of the variability from the comparision between the observational results and the stellar spots models or the inhomogeneous circumstellar model. From the results of these comparisions we find that for one classical T Tauri star the observational results can be reproduced by a cold spot and for another 5 by hot spots. Nevertheless, for these 5 stars the variability in the U band (3600 Å) cannot be reproduced by the hot spot model, there must be another mecanism that causes the anomalous behaviour at short wavelengths. The variable Ae/Be Herbig stars do not always show a regular behavior with wavelength so we can only assign an origin for the variability of two of them.

Our observational results suggest a trend: the larger the mass loss rate, the larger the amplitud of the optical continuum variations. This trend is analyzed in detail through the comparision between the amplitud of the optical continuum variations and the equivalent width of the H$_\alpha$ emission. The optical continuum arises from the stellar photosphere, while the H$_\alpha$ emission is assigned to the internal regions (close to the star) of the wind. For the Ae/Be Herbig stars there is not a clear relation between both quantities, but we have found a direct relation for the classical T Tauri stars: for those objects with H$_\alpha$ equivalent width lower than 30 Å we found variations lower than 0.1 mag and for the others there is a direct relation between the continuum variability and the equivalent width of the H$_\alpha$ emission. Taking into account the correlation found by Cabrit et al. (1990) between H$_\alpha$ emission and the excess of infrared luminosity, that is, between mass loss and mass accretion, we conclude that there is a relation between the optical continuum variability and the accretion process: for those objects with larger accretion rate the amplitud of the variability is larger (variability due to hot spots). As has been already suggested, these hot spots could be the regions of the stellar surface where the material from the accretion disks falls.

Tidally-induced warps in the disks of young stellar objects

Caroline Terquem

Thesis work conducted at: Laboratoire d'Astrophysique, Université Joseph Fourier / CNRS, Grenoble, France

Current address: Laboratoire d'Astrophysique, Observatoire de Grenoble, BP 53X, 38041 Grenoble Cedex, France

Address as of November 1993: Queen Mary and Westfield College, Dept. of Mathematics, Mile End Road, London E1 4NS, UK

Electronic mail: terquem@gag.observ-gr.fr

Ph.D dissertation directed by: Claude Bertout

Ph.D degree awarded: September 1993

Observations show that a majority of T Tauri stars are binary systems. This led us to study tidal effects induced by a stellar companion on the disk surrounding a T Tauri star.

We first calculated the tidally-induced perturbation in both cases of self-gravitating and accretion circumstellar disks. In order to obtain an analytical solution, we assumed that the perturbation was small. The amplitude of the obtained deformation then reaches 1% of the radius of the disk in the case of an accretion disk, and 10% in the case of a self-gravitating disk.

To evaluate the influence of this deformation on the spectral energy distribution, we then calculated the energy emitted in a given direction by the warped disk and its central star, taking into account the shadowing of the star by the disk and of the disk by the star.

We applied these computations to young stellar objects. In the case of small perturbations, when the separation between the two stars is greater than a hundred of astronomical units, tidal effects in circumstallar disk have a significant effect on the submillimetric range of the spectral energy distribution. We demonstrated that the energy emitted in this range is 2 to 20 times the energy emitted by a flat disk. This result will be tested by future submillimetric observations.

In order to evaluate the possible influence of tidal effects in closer binary systems, we then parametrized the deformation. This model allowed us to reproduce spectral energy distributions of T Tauri stars with strong infrared excess. Also, the resulting spectral energy distributions led us to propose a new interpretation of Class I young stellar objects: a Class I spectral energy distribution can result from hidding a T Tauri star in a warped disk. Possible observational support of this model is given by recent millimetric observations of Andre and Montmerle, who showed that the mass of matter surrounding Class I objects may not be very different from the mass of matter surrounding T Tauri stars.

Finally, we performed a preliminary study of the influence of the deformation on the accretion rate in the disk and concluded that tidal forces in the disk acts as a pseudo-viscosity that may produce disk accretion.

New Books

Dust and Chemistry in Astronomy
edited by T.J.Millar and D.A.Williams

1. Dust and Astrochemistry: An Introduction
T.J.Millar and D.A.Williams

2. Observations of Molecular Ices
D.C.B.Whittet

3. Observations of Hot Molecular Cores
C.M.Walmsley and P.Schilke

4. Molecular Hydrogen Emission from Star-forming Regions
P.W.J.L.Brand

5. Carbonaceous Grains
W.W.Duley

6. PAHs and Astrochemistry
A.G.G.M.Tielens

7. Physical and Chemical Processes on Dust
D.A.Williams

8. Interstellar Dust and the Chemistry of Diffuse Clouds
R.Wagenblast and D.A.Williams

9. Gas-Grain Chemistry in Quiescent Dense Interstellar Clouds
E.Herbst

10. The Chemistry in Low Mass Star Formation
T.W.Hartquist, L.A.M.Nejad and D.A.Williams

11. Clump Collapse and Star Formation
J.M.C.Rawlings

12. The Chemistry of Hot Molecular Cores
T.J.Millar

13. Laboratory Dust Studies and Gas-Grain Chemistry
J.M.Greenberg, C.X.Mendoza-Gomez, M.S.de Groot and R.Breukers

14. Irradiation of Molecular Ices
V.Pirronello

IOP Publishing, Bristol, Philadelphia and New York

The Graduate Series in Astronomy, 334 pages

ISBN 0 7503 0271 2 hardcover 79.00 pounds or 149 dollars

Postage:
UK/RoW: 7.50 pounds for any order over 50.00 pounds
US: 2.75 dollars for first book, then 75c per book
Canada: 7.50 dollars for first book, then 75c per book
All major credit cards accepted.

Phone and fax numbers:
UK/RoW: +44 272 297481 (fax 294318)
USA: toll-free 1-800-488 2665 (fax 802 878 1102)
e-mail orders and queries: bancroft@ioppublishing.co.uk

Protostars and Planets III

Edited by E.H.Levy and J.Lunine

Proceedings from a conference held in Tucson, Arizona, USA in March 1990

1. The Collapse of Clouds and the Formation and Evolution of Stars and Disks/*F.Shu, J.Najita, D.Galli, E.Ostriker, S.Lizano*

2. Nucleosynthesis and Star Formation/*A.G.W.Cameron*

3. Classical Novae: Contributions to the Interstellar Medium/*R.D.Gehrz, J.W.Truran, R.E.Williams*

4. Formation of Interstellar Clouds and Structure/*B.G.Elmegreen*

5. Giant Molecular Clouds/*L.Blitz*

6. The Chemical Evolution of Protostellar and Protoplanetary Matter/*E.F. van Dishoeck, G.A.Blake, B.T.Draine, J.I Lunine*

7. Environments of Star Formation: Relationship between Molecular Clouds, Dense Cores and Young Stars/*E.A.Lada, K.M.Strom, P.C.Myers*

8. Magnetic Fields in Star-Forming Regions: Observations/C.Heiles, A.A.Goodman, C.F.McKee, E.G.Zweibel

9. Magnetic Fields in Star-Forming Regions: Theory/*C.F.McKee, E.G.Zweibel, A.A.Goodman, C.Heiles*

10. Stellar Multiple Systems: Constraints on the Mechanisms of Origin/*P.Bodenheimer, T.Ruzmaikina, R.D.Mathieu*

11. Pre-Main Sequence Evolution and the Birth Population/*S.W.Stahler, F.M.Walter*

12. The Initial Stellar Population/*H.Zinnecker, M.J.McCaughrean, B.A.Wilking*

13. Young Stars: Episodic Phenomena, Activity and Variability/*L.Hartmann, S.Kenyon, P.Hartigan*

14. The Occurrence and Properties of Disks around Young Stars/*S.V.W.Beckwith, A.I.Sargent*

15. T Tauri Stars and Their Accretion Disks/*G.Basri, C.Bertout*

16. Energetic Mass Outflows from Young Stars/*S.Edwards, T.Ray, R.Mundt*

17. Molecular Outflows/*Y.Fukui, T.Iwata, A.Mizuno, J.Bally, A.P.Lane*

18. Origin of Outflows and Winds/*A.Königl, S.P.Ruden*

19. Magnetic Fields, Activity and Circumstellar Material around Young Stars/ *T.Montmerle, E.D.Feigelson, J.Bouvier, P.André*

20. Transport Processes and the Evolution of Disks/*F.C.Adams, D.N.C.Lin*

21. On the Tidal Interaction between Protostellar Disks and Companions/*D.N.C.Lin, J.C.B.Papaloizou*

22. Evolutionary Time Scales for Circumstellar Disks Associated with Intermediate- and Solar-Type Stars/*S.E.Strom, S.Edwards, M.F.Skrutskie*

23. Extinct Radionuclides and Evolutionary Timescales/*T.D.Swindle*

24. Physical and Isotopic Properties of Surviving Interstellar Carbon Phases/*U.Ott*

25. Energetic Particle Environment in the Early Solar System: Extremely Long Pre-Compaction Meteoritic Ages or an Enhanced Early Particle Flux/*D.S.Woolum, C.Hohenberg*

26. Formation of the Protosolar Nebula/*W.M.Tscharnuter, A.P.Boss*

27. Physical Processes and Conditions Associated with Formation of Protoplanetary Disks/*G.Morfill, H.Spruit, E.H.Levy*

28. Meteoritic Constraints on Conditions in the Solar Nebula/*H.Palme, W.V.Boynton*

29. Chemistry and Evolution of Gaseous Circumstellar Disks/*R.G.Prinn*

30. Formation of Planetesimals in the Solar Nebula/*S.J.Weidenschilling, J.N.Cuzzi*

31. Growth of Planets from Planetesimals/*J.J.Lissauer, G.R.Stewart*

32. Planetary Accretion in the Solar Gravitational Field/*K.Ohtsuki,S.Ida,Y.Nakagawa,K.Nakazawa*

33. Gaseous Accretion and the Formation of Giant Planets/*M.Podolak, W.B.Hubbard, J.B.Pollack*

34. Origin of the Outer-Planet Satellites/*J.I.Lunine, W.C.Tittemore*

35. Comets and the Origin of the Solar System: Reading the Rosetta Stone/*M.J.Mumma, P.Weissman, S.A.Stern*

36. Main-Sequence Stars with Circumstellar Solid Material: The Vega Phenomenon/ *D.E.Backman,F.Paresce*

37. Planetary Noble Gases/*K.Zahnle*

38. Impacts and the Early Environment and Evolution of the Terrestrial Planets/ *H.J.Melosh, A.M.Vickery, W.B.Tonks*

39. The Long-Term Dynamical Evolution and Stability of the Solar System/*M.J.Duncan, T.Quinn*

ISBN 0-8165-1334-1

1596 pages, 110 illustrations

$90.00 + shipping ($3.00 for first book, $1.50 each additional,
outside North America $4.00/$2.00). Credit cards accepted.

The University of Arizona Press
1230 N.Park Ave., Tucson, AZ 85719, USA
Tel. 1-800-426-3797/ Fax. 1-602-621-8899

New Jobs

POSTDOCTORAL RESEARCH ASSISTANT IN STAR FORMATION

QUEEN MARY & WESTFIELD COLLEGE (UNIVERSITY OF LONDON)
Department of Physics
Mile End Road,
London E1 4NS,

The Department of Physics seek a research assistant who, in collaboration with Dr Jim Emerson, will contribute to an observationally based study of the mechanism of low mass star formation, including the properties, structure and composition of associated disks and envelopes, indicators of dust grain size and temperature, and interactions with the parent cloud. The current program involves infrared to mm observations of YSOs embedded in cores and of T Tauri systems, data reduction, and associated modelling. Infrared Space Observatory time will be sought. Data processing and modelling uses QMW's VAX and SUN based Starlink computing systems.

Applicants must have, or be about to obtain, a PhD, and should have experience in the field of star formation, although those with other related experience will be considered.

The appointment is for 2 years in the first instance and is funded by an SERC rolling grant with a starting salary in the range £14,962-19,513 pa inclusive, depending on age and experience. The post is open from 1 Nov.

For further printed details and an application form please telephone 071-975-5171 (24 hour answerphone) or FAX 081-983-3440 quoting Reference 93102. Completed application forms should be submitted by 1 November 1993 to the Recruitment Coordinator, Personnel Office, Queen Mary & Westfield College, Mile End Road, London E1 4NS, UK.

Informal enquiries may be made to: Dr J P Emerson
e-mail 19764::JPE(SPAN), jpe@starlink.qmw.ac.uk (internet)
Direct Tel: 071-975-5040 Physics Dept FAX: 081-981-9465