THE STAR FORMATION NEWSLETTER

An electronic publication dedicated to early stellar evolution and molecular clouds

No. 1 — 8 Oct 1992 Editor: Bo Reipurth (reipurth@eso.org)

Editorial

This is the first issue of a newsletter destined for astronomers interested in the formation and early evolution of stars, associated phenomena and molecular clouds, observationally as well as theoretically. It will appear approximately once a month and will be distributed exclusively via e-mail.

The principal goal of this endeavour is to give the community easy and rapid access to the latest results as reported in papers newly accepted for publication. Each issue will contain the abstracts of papers accepted during the preceding month.

The motivations for starting such a newsletter are several. The pace and volume of work in the field of star formation is ever increasing. Keeping up with the literature is a losing battle for most of us. Moreover, the considerable production time for most journals render even newly published papers somewhat removed from the actual research frontier. Also preprints have their problems: they are bulky and expensive to distribute and institutes therefore often wait to mail them until a sufficient number has accumulated, sometimes causing substantial delays. In these times of soaring costs, several institutions have stopped issuing preprints altogether. Finally, most of us find time to read only the abstract of a new paper, anyway, unless it is precisely within our special field of current work.

E-mail has now reached a very high level of reliability and is almost universally available. It permits cheap and instant distribution of information. I have therefore, after consultation with and encouragement from many colleagues, decided to launch this newsletter as an experiment initially for one year. In the beginning the goal will be mostly limited to distributing abstracts of papers accepted for publication in refereed journals, but also announcements of meetings, new books, job offers, etc. will occasionally appear. In January a special issue will be distributed with abstracts of Ph.D. theses obtained during 1992 in the field of star formation and molecular clouds. Other activities are also under discussion.

To be successful and as complete as possible, the newsletter should reach a large fraction of the star formation community. This first issue is circulated to the about 100 e-mail addresses I happen to have. Please let your colleagues know that they are welcome to be added to the mailing list.

The present issue contains abstracts of preprints I have received or have found in our library, and is as such very incomplete. Neither I nor our secretary are very inclined to type hundreds of abstracts over the next year, so we have made a simple LaTeX macro that anybody can fill out even without knowledge of LaTeX. Making the newsletter thus becomes a communal effort: you will every month receive the results of everybody else if you will agree to contribute your own. To receive the macro and further issues of the newsletter please send a brief reply and indicate any changes to your e-mail address (we prefer Internet addresses). After receiving the macro, please send abstracts of your recently accepted papers. If you do not wish to receive further issues, you do not have to do anything.

Bo Reipurth

Abstracts of recently accepted papers

Sub-Millimeter Continuum Observations of ρ OPH A: The Candidate Protostar VLA 1623 and Pre-Stellar Clumps

Philippe André[1], Derek Ward-Thompson[2] and Mary Barsony[3]

[1] Service d'Astrophysique, Centre d'Etudes de Saclay, F–91191 Gif-sur-Yvette Cedex, France
[2] Mullard Radio Astronomy Observatory, Cavendish Laboratory, Madingley Road, Cambridge CB3 0HE, England
[3] Harvard-Smithsonian Center for Astrophysics, MS–78, 60 Garden Street, Cambridge, MA 02138, USA

We have mapped the sub-millimeter continuum emission from the rich star-forming core, ρ Oph A, at 350, 450, 800 and 1300μm using the JCMT and IRAM 30-m telescopes. In addition to the diffuse emission from the cloud core itself, these observations reveal four well-defined clumps, which, surprisingly, are barely visible in the single-dish molecular maps obtained so far in this region. The gas may have partially frozen out onto the dust grains, due to low temperature and/or high density in the clumps. We discuss the possibility that these clumps are pre-stellar or extremely young, low-mass protostars. One of them coincides with the (cm) radio source VLA 1623 which drives one of the youngest and best collimated CO bipolar flows known to date.

Supplementing our JCMT measurements with stringent upper limits obtained at all four IRAS bands by Maximum Entropy Deconvolution of the raw IRAS data, we show that VLA 1623 is a highly obscured ($A_V \gtrsim 1000$) young stellar object (YSO) with a remarkably low bolometric luminosity ($L_{bol} \lesssim 1\ L_{\odot}$) and dust temperature ($T_d \lesssim 20$ K). Its spectral energy distribution is well fitted by a single modified blackbody from dust at $15-20$ K with an opacity index $\beta = 1.5$. This indicates a mass of circumstellar material $M_C \sim 0.6 M_{\odot}$ and a bolometric luminosity $L_{bol} \sim 1\ L_{\odot}$.

Our sub-mm observations resolve a nearly spherical dust envelope around VLA 1623, of FWHM size $\approx$ 2000 AU roughly independent of wavelength. This suggests that the bulk of the circumstellar mass of VLA 1623 is distributed in an "apple-like" structure rather than a disk. Detailed, spherical modelling of this dust structure, using the radiative transfer code of Wolfire & Cassinelli, shows the spectral energy distribution and sub-mm intensity profiles of VLA 1623 can be fitted *simultaneously* by a 1 $L_{\odot}$ internal source surrounded by a circumstellar envelope with a surprisingly shallow density distribution ($\rho(r) \propto r^{-0.5}$).

The remarkably cold temperature, high internal obscuration, and relatively massive circumstellar structure of VLA 1623 all point to an extremely young object, perhaps a true protostar. We compare VLA 1623 with a few other very young embedded sources similarly characterized by very low values of the ratio L_{bol}/L_{submm}, and suggest that these objects define an entirely new class of YSOs, which we call "Class 0" to indicate their extreme youth. Although these strong sub-mm YSOs are invisible in the near- and mid-IR, they are already powering highly collimated outflows (opening angles $< 30°$) with great efficiency (L_{flow}/L_{bol} up to $\sim 50\%$). This may indicate that the outflow phenomenon starts earlier than previously thought in (proto)stellar evolution, i.e., prior to the near-IR Class I phase as in the scheme devised by Lada.

Accepted by Astrophys. J.

VLBI Survey of ρ Ophiuchi: A Population of Magnetized, Diskless Young Stellar Objects

Philippe André[1], Bryan D. Deeney[2], Robert B. Phillips[3] and Jean-François Lestrade[4]

[1] Service d'Astrophysique, Centre d'Etudes de Saclay, F–91191 Gif-sur-Yvette Cedex, France
[2] Department of Astronomy and Astrophysics, Villanova University, Villanova, PA 19085, USA
[3] Massachusetts Institute of Technology, Haystack Observatory, Westford, MA 01886, USA
[4] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91106, USA

In the past years, extensive radio-continuum surveys conducted with the Very Large Array (VLA) have shown that only ~ 10 of the ~ 100 young stellar objects (YSOs) embedded in the central region of the ρ Ophiuchi molecular cloud have "strong" radio emission above $S_{6cm} = 1$ mJy. Two of these ρ Oph radio stars, S1 and DoAr 21, have recently been detected and resolved by Very Long Baseline Interferometry (VLBI), implying that their radio emission is "peristellar", i.e., originates in magnetic structures up to $\sim 25\ R_*$ in diameter. We report here VLBI observations of nine other ρ Oph YSOs, yielding positive detections in five cases (VSSG 14, WL 5, ROC 16, ROX 39, and VSSG 11), with flux densities ranging from 1.2 to 9 mJy at 3.6 cm. In contrast, while simultaneously detected by the VLA at

levels of a few mJy, the protostellar outflow source IRAS 16293 and the "protostar" candidate YLW 15 were apparently over-resolved and undetected on the VLA-Goldstone baseline. The radio emission from the young A star VSSG 14 was measured to be circularly polarized, at a level ($\sim 6\%$) comparable to what had previously been observed for the embedded magnetic B star S1.

The brightness temperatures (T_b) measured for the VLBI-detected YSOs range from $\sim 10^7$ to $\gtrsim 8 \times 10^7$ K, unambiguously establishing that these radio sources are nonthermal, and not the result of circumstellar ionized winds as is probably the case for IRAS 16293 and YLW 15.

The present VLBI observations thus confirm our earlier suggestion that most "strong" ($S_{6cm} \gtrsim 1$ mJy) stellar radio sources of ρ Oph are magnetic in character (i.e. nonthermal). When optically visible, these radio emitters are associated with "weak-line" T Tauri stars (DoAr 21, ROX 39) or young B–A stars without emission lines (S1 and VSSG 14). Others are optically-invisible, low luminosity YSOs with no or little infrared excesses (e.g., WL 5, VSSG 11). It appears that these nonthermal radio-emitters make up a specific class of YSOs characterized by the absence of dense circumstellar disks and the presence of extended, organized magnetic structures reminiscent of those found around magnetic Bp–Ap stars. Remarkably, the magnetized radio YSOs of ρ Oph are spatially more concentrated towards the cloud core than the majority of T Tauri stars, suggesting they are younger. Some of the youngest YSOs may thus be already "naked".

It is tempting to speculate that, compared to classical T Tauri stars, the diskless, nonthermal radio stars have conserved particularly strong fossil magnetic fields, which caused fast clearing of their circumstellar material.

Accepted by Astrophys. J.

Near-IR Observations of the Bipolar Outflow Sources IRAS03271+3013 and IRAS03282+3035

C. Aspin

Joint Astronomy Center, 660 N. A'Ohoku Place, University Park, Hilo, Hawaii, 96720, USA

We present near-IR imaging and spectroscopy of the newly discovered CO molecular outflow sources associated with IRAS03271+3013 and IRAS03282+3035. We have identified the central exciting source in IRAS03271+3013 which lies within 5″ of the IRAS coordinates. The star is heavily reddened, has bright molecular hydrogen (H_2) line emission and appears surrounded by a faint nebula $\sim 5''$ in extent. Diffuse emission possibly extends to the north of the object. The H_2 line fluxes suggest that the emission is shock-excited and that the line emission region is overlaid by ~ 51 magnitudes of visual extinction. No stellar sources were detected within 30″ of the coordinates of IRAS03282+3035 implying the exciting source of this outflow is considerably more obscured than that of IRAS03271+3013.

Accepted by Astron. and Astrophys.

Mid–IR Spectroscopy of GGD27-IRS: Evidence for a PMS Stellar Cluster

C. Aspin, T.R. Geballe

Joint Astronomy Center, 660 N. A'Ohoku Place, University Park, Hilo, Hawaii, 96720, USA

We present mid–IR spectroscopy of 5 objects in the bipolar outflow source and near–IR reflection nebula GGD27–IRS. The sources IRS1, IRS3 and Objects *a* and *b* are all bright at 10 μm and possess strong emission features at 8.6 μm, 11.3 μm and 12.6 μm typical of the unidentified (UIR) emission b ands seen in many nebulae. IRS2 is also bright at 10μm and possesses a silicate absorption band and weak UIR bands, the latter probably the result of contamination from the nearby sources Objects *a* and *b*. The presence of the UIR bands at four distinct locations in GGD27–IRS implies each location is being irradiated by UV flux and suggests there are several intermediate — to high — mass young stellar objects in this region. The bright nature of these spatially well-separated sources in the mid–IR supports this hypothesis and suggests that there must exist local sources of heating in each region. We discuss both the observed spectral features and the near — to mid- – IR colours of the sources and demonstrate the value of mid–IR photometry in separating circumstellar emission from interstellar and molecular cloud reddening. We conclude that GGD27–IRS is in fact, a young pre-main sequence cluster with at least three, and probably more, members.

Accepted by Astron. and Astrophys.

Fabry-Perot Imaging of Molecular Hydrogen in NGC2071

C. Aspin, G. Sandell, D.M. Walther

Joint Astronomy Center, 660 N. A'Ohoku Place, University Park, Hilo, Hawaii, 96720 U.S.A.

We present Fabry-Perot images of the $v = 1 - 0$ S(1) ($\lambda = 2.122\ \mu$m) line of molecular hydrogen (H_2) in the core region of the energetic bipolar outflow source associated with NGC2071. Using a Fabry-Perot with a FWHM of 100 km s^{-1}, we have fully-sampled the velocity range -167 km s^{-1} to $+167$ km s^{-1} from the wavelength of peak flux obtaining a velocity cube of 11 images; each image covers an area of $\sim 36'' \times 36''$ at a spatial resolution of $0.62''$/pixel. From these data, we have studied the small (spatial) scale intensity structure of the line emission, the gross velocity characteristics of the region and the ratio of line to continuum emission over the source. We find that the S(1) emission is highly structured on spatial scales of a few arcseconds, peaks in intensity directly on IRS1. Two additional S(1) emission peaks are placed symmetrically about IRS1 and form a compact bipolar-type nebula. Our relatively crude velocity mapping indicates that the north-east condensation is predominantly blue-shifted with respect to IRS1 while the south-west condensation is mostly red-shifted. This is in the same sense as earlier CO, CS and H_2 low resolution maps which show clumpiness on much larger scales. In addition, we observe symmetric emission structure centered on IRS2. In this case, the emission peak south-east of IRS2 is red-shifted relative to the emission peak to the north-west suggesting that IRS2 may drive a relatively compact bipolar outflow almost orthogonal to that of IRS1. The data presented here, together with evidence from previous observations, suggests that IRS1, IRS2 and possibly IRS3 are all self-luminous PMS stars at similar evolutionary stages.

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

Molecular Line Emission from Circumstellar Disks

Steven V. W. Beckwith[1] and Anneila I. Sargent[2]

[1] Max-Planck-Institut für Astronomie, Königstuhl, D–6900 Heidelberg 1, Germany; and Cornell University.
[2] Division of Physics, Mathematics, and Astronomy, California Institute of Technology, USA

Calculations of the molecular line emission from circumstellar disks around young stars show the transitions of CO and its common isotopes, ^{13}CO and C^{18}O, to have typical line-center optical depths between 100 and 1000. The line emission reflects the temperature distribution within the disks and *not* the mass distribution as previously suggested. The ^{13}CO line fluxes from the HL Tau and two similar stars show that the outer disk temperatures are, indeed, higher than expected for normal accretion disks, as inferred from far-infrared continuum data. The line radiation indicates that the disks are *at least* 400 AU in extent. The very high optical depths in the CO lines imply that as little as $6 \times 10^{-6} M_\odot$ of gas may be detected around very young stars with existing instrumentation.

Accepted by Astrophys. J.

Fragmentation of Elongated Cylindrical Clouds IV. Clouds with Solid-Body Rotation about an Arbitrary Axis

Ian Bonnell[1], Jean-Pierre Arcoragi[1−2], Hugo Martel[1−3] and Pierre Bastien[1]

[1] Montreal Star Formation Group, Département de Physique, Université de Montréal, C.P. 6128, Succ. A, Montréal, Que, H3C 3J7, Canada; and Observatoire du Mont-Mégantic, Canada
[2] Canadian Institute for Theoretical Astrophysics
[3] Current address: Department of Astronomy, University of Texas, Austin, TX, 78712, USA

Three-dimensional hydrodynamic collapse calculations of elongated isothermal clouds with solid-body rotation about an arbitrary axis are presented. Four parameters are required to specify our models: the ratio of length to diameter of the cylinders, L/D, the initial Jeans number J_0 (ratio of the absolute value of gravitational to thermal energies), and the ratio of the absolute value of the rotational to gravitational energies for the components of rotation parallel and perpendicular to the cloud's major axis, $\beta_\parallel$ and $\beta_\perp$ respectively. Four different modes of fragmentation are identified. In all evolutions that formed more than one fragment, a structural fragmentation mode occurred first, forming condensations on each side of the cylinder. This mode is referred to as Binary Fragmentation. For low J_0 and $\beta_\parallel$, the Binary Fragments evolve into a binary system with each fragment surrounded by a disk. These disks are parallel but not coplanar.

At higher J_0, the circumfragmentary disks fragment (Disk Fragmentation) due to their mutual gravitational interaction. With a higher value of $\beta_{\|}$, fragmentation occurs via an intermediary bar stage (Bar Fragmentation). In some cases, the bar fragments into one subcondensation and a spiral arm which subsequently fragments (Bar-Arm Fragmentation). The occurrence of these modes is located in the parameter space J_0 and $\beta_{\|}$. The parameter $\beta_{\perp}$ also has some effect on the outcome, but it does not determine the types of fragmentation modes. The multiple systems formed by these processes are not coplanar. Fragmentation processes considered in previous studies cannot explain the observation that at least one third of multiple systems are non-coplanar. This was our main motivation for introducing rotation about arbitrary axis.

The calculations show that gravitational torques and tidal effects control most of the fragmentation and coalescence which occur. The fragmentation processes and gravitational torques can also reduce the fragment's specific angular momentum by up to two orders of magnitude compared to that of the parent cloud. This is consistent with the inferred value of the specific angular momentum of the initial protosolar nebula.

The importance of considering star formation on a large scale is clear from the presence of these new fragmentation modes. This gives an indication of the dynamical processes involved in the fragmentation of large molecular cloud complexes.

Accepted by Astrophys. J.

Fragmentation of Elongated Cylindrical Clouds V. Dependence of Mass Ratios on Initial Conditions

Ian Bonnell and Pierre Bastien

Montreal Star Formation Group, Département de Physique, Université de Montréal, C.P. 6128, Succ. A, Montréal, Que, H3C 3J7, Canada; and Observatoire du Mont-Mégantic, Canada

Calculations of the formation of non-equal mass binary and multiple systems are presented. The systems are the result of the collapse and fragmentation of rotating elongated clouds which is followed using a three-dimensional smooth particle hydrodynamics (*SPH*) code. The rotation is parameterized by components parallel and perpendicular to the cloud's major axis. The effects of the rotation, the initial Jeans number J_0 (ratio of the absolute value of gravitational to thermal energies), and the cloud's initial density profile are investigated. Binary formation results from the elongated shape of the initial cloud, one fragment forming on each side of the equatorial plane. Slight linear density gradients along the cloud's major axis are sufficient to form non-equal mass fragments. Resultant mass ratios range from 0.1 to 1.0, in agreement with observations. The spatial resolution can affect the mass ratio, especially for low J_0 where the fragments form closer together and tidal forces are important.

In the presence of rotation, the fragments form with surrounding disks. The accretion rate of the cloud onto the disks and of the disks onto the fragments is found to be greatly affected by tidal interactions at the fragments' closest approach. Accretion onto both the primary and the secondary in enhanced at closest approach due to the tidal forces. The tidal forces depend on the system's mass ratio such that in an unequal mass system the secondary's disk can be completely decimated through accretion. Due to its orbital motion around the primary, the secondary can directly accrete the matter that has gathered in the primary's disk. The secondary is thus less likely to have an appreciable disk, accounting for a redder primary. The binary system's initially high eccentricity decreases with the continued accretion of higher specific angular momentum at apastron and lower specific angular momentum matter at periastron. Multiple systems with unequal mass components are also formed. The systems are composed of an inner binary and a more distant companion. The mass ratio of the companion-binary system is usually less than that of the binary.

Accepted by Astrophys. J.

Mass Loss from Pre-Main Sequence Accretion Disks. I. The Accelerating Wind of FU Orionis

Nuria Calvet[1], Lee Hartmann[2] and Scott J. Kenyon[2]

[1] Centro de Investigaciones de Astronomía, Mérida, Venezuela
[2] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

We present evidence that the wind of the pre-main sequence object FU Orionis arises from the surface of the luminous accretion disk. A disk wind model calculated assuming radiative equilibrium explains the differential behaviour of the observed asymmetric absorption line profiles. The model predicts that strong lines should be asymmetric and blueshifted, while weak lines should be symmetric and double-peaked due to disk rotation, in agreement with observations. We propose that many blueshifted "shell" absorption features are not produced in a true shell of material, but rather form in a differentially expanding wind that is rapidly-rotating. The inference of rapid rotation supports the proposal that pre-main sequence disk winds are rotationally-driven. FU Ori may lose substantial amounts of mass over a significant area of the innermost disk (~ 10 stellar radii), which could have important implications for the structure of jets from young stellar objects. Our results support the suggestion that massive winds originate from rapidly-accreting pre-main sequence accretion disks.

Accepted by Astrophys. J.

A Kinematical Study of the Jet GGD 34

Ana I. Gómez de Castro[1], L. F. Miranda[2] and C. Eiroa[3]

[1] ESA IUE Observatory, P.O. Box 50727, 28080 Madrid, Spain
[2] Departamento de Astrofísica, Universidad Complutense de Madrid, 28040 Madrid, Spain
[3] Departamento de Física Teórica, C–XI, Facultad de Ciencias, Universidad Autónoma de Madrid, 28049 Madrid, Spain

CCD images and spectra of high spectral resolution of GGD 34 are analyzed. The object is a jet consisting of three major condensations separated 0.08 pc from each other and aligned over 0.17 pc in the East-West direction. The three condensations emit strongly in [S II], [N II] and Hα. The westernmost condensation has also significant continuum emission coming from what seems to be the bow-shaped borders of a cavity. A detailed study of the excitation conditions, densities and velocity field is presented. The excitation of the object is very low and the line ratios can be reproduced by mild radiative shocks at velocities ≤ 40 km/s. The radial velocity of the gas is high, $\simeq 180$ km/s, indicating that the excitation is much lower than expected if the flow kinetic energy is fully spent into gas heating. This is generally observed in Young Stellar Objects (YSO) jets. The exciting source of the outflow seems to be located at the western end of GGD 34, illuminating the cavity.

The two easternmost condensations GGD 34/B and GGD 34/C are connected by a neatly shaped lobe emitting in [S II] and Hα. The width of the lobe varies from 0.012 pc in the condensations to 0.034 in the space in between. The lobe is not symmetric, with respect to the jet axis, but has a rather sinusoidal morphology. The velocity field in this region also can be well fitted by a sine curve. Morphology and velocity field are correlated; however they are not accompanied by significant changes in the excitation degree. We suggest that the properties of GGD 34 are produced by a 'kink' plasma instability.

Accepted by Astron. and Astrophys.

The Structure of Magnetic Fields in Dark Clouds: Infrared Polarimetry in B216–217

Alyssa A. Goodman[1], Terry J. Jones[2], Elizabeth A. Lada[3] and Philip C. Myers[3]

[1] Astronomy Department, University of California, Berkeley, CA 94720, USA
[2] School of Physics and Astronomy, University of Minnesota, 116 Church Street, S.E., Minneapolis, MN 55455, USA
[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

We present a near-infrared polarization map of background starlight seen through the B216–217 dark cloud in Taurus. The mean direction and dispersion in direction of the polarization vectors observed in the near-infrared are indistinguishable from the direction and dispersion of optical polarization vectors around the periphery of the dark cloud. Measurements of J and K magnitudes of the stars observed in the near-infrared imply a range of extinctions

$1 \lesssim A_V \lesssim 10$ mag, while the mean A_V for the stars whose polarization has been measured optically is $\lesssim 1$ mag. Assuming that grains in the high- and low-density regions are similar, and are similarly aligned by magnetic fields, then unless the field becomes significantly more nonuniform in denser regions, *our results imply that the dark cloud has no effect on the projected direction of the magnetic field*. If the field does become more nonuniform in the denser portions of the cloud, then the dark cloud is associated with a change in the total energy of the field, but not with any change in the mean direction of the field. Yet, we also find that the degree of polarization in B216–217 and other dark clouds increases more slowly with extinction than expected: if this reduction in polarization efficiency is caused by a drop in alignment and/or polarizing efficiency in denser regions, *it is possible that near-infrared polarization may be relatively insensitive to the field direction in the dense interior of dark clouds.*

Accepted by Astrophys. J.

An Optical/Infrared/Millimetre Study of HH90/91

Roland Gredel[1], Bo Reipurth[1] and Steve Heathcote[2]

[1] European Southern Observatory, Casilla 19001, Santiago 19, Chile
[2] Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatories, Casilla 603, La Serena, Chile

A detailed multi-wavelength study of the group of Herbig-Haro objects, HH90/91, is presented. Narrow band CCD images have been obtained in Hα and [SII] which encompass the whole complex. The excitation distribution, inferred from an H$\alpha -$ [SII] difference frame, is that expected for a bipolar flow which rams into the ambient interstellar medium. Proper motions were determined for several knots in the complex. The vectors are directed away from the stationary HH91A in which we have found a faint infrared source. The various knots in HH91 have dynamical timescales of a few thousand years. HH90, if ejected from HH91A, has a dynamical age of about 24000 years. Most of the knots show an extremely low-excitation optical spectrum, with [SII]/H$\alpha \approx 2$ and absent or weak [NII]6548+84 emission. This indicates that the shock velocity is of the order of $10 - 30$ km s^{-1}. Electron densities inferred from the [SII]6717/6731 ratio are of the order of a few hundred cm^{-3}.

High-resolution long-slit spectra in the near-infrared were obtained towards HH91A. The molecular hydrogen emission is extremely peaked towards HH91A. It reaches a maximum surface brightness of 4.7×10^{-10} W cm^{-2} sr^{-1} in the (1,0) S(1) line of H_2. This is about a factor of two higher than measured in HH43, the brightest HH object known previously. The infrared spectrum is dominated by a multitude of H_2 emission lines. The population densities inferred for the various vibration-rotation levels follow a thermal distribution characterized by an excitation temperature of 2750 K.

Millimetre emission line observations of ^{13}CO $(1 - 0)$ show that HH91 is located at a strong density gradient in the surrounding molecular material. CS $(2 - 1)$ emission was, however, not detected around HH91A. It appears that HH90/91 is in an advanced state of evolution.

Accepted by Astron. and Astrophys.

Kinematics and Evolution of the HH34 Complex

Steve Heathcote[1] and Bo Reipurth[2]

[1] Cerro Tololo Inter-American Observatory, National Optical Astronomy Observatories, Casilla 603, La Serena, Chile
[2] European Southern Observatory, Casilla 19001, Santiago 19, Chile

We discuss the kinematics and evolution of the HH 34 complex based on accurate proper motions and radial velocities. We find that the bow shocks on opposite sides of the source recede from it at highly supersonic velocities (~ 330 km s^{-1}) along a tightly defined axis inclined at an angle of $\sim 30°$ to the plane of the sky. The space velocity we determine for the HH 34 bow shock is substantially greater than its shock velocity, ~ 160 km s^{-1}, derived spectroscopically. These observations can only be reconciled if HH 34 advances into a medium already moving away from the source at a velocity ~ 170 km s^{-1}. We have detected faint emission, at the appropriate radial velocity, from the region just ahead of HH 34. The existence of multiple bow shocks in the approaching lobe of the flow indicates that the driving source has experienced repeated episodes of enhanced mass loss at intervals ~ 400 years. We speculate that each successive outflow imparts an impulse to the ambient medium incrementally accelerating it to a large fraction of the outflow velocity. Consistent with this idea the flux of momentum now carried by the moving medium ahead of HH 34 is found to be comparable to that in the extant outflows. The knots in the HH 34 jet also have substantial space motions

($\sim$ 220 km s^{-1}) and thus cannot be stationary crossing shocks. We find that the relative brightness of these knots changes with time. Comparing this *temporal* change with the *spatial* trend in knot brightness suggests that the knots represent a train of similar shock waves, the physical parameters of which evolve as they propagate along the jet. The width of the knots begins to increase, and their electron density to decrease, precisely at the point where they begin to fade. The behaviour of the knots is discussed in the context of current models for knot production in astrophysical jets.

Accepted by Astron. J.

Cold Dust around Herbig-Haro Energy Sources: A 1300 μm Survey

Bo Reipurth[1], R. Chini[2], E. Krügel[2], E. Kreysa[2] and A. Sievers[2]

[1] European Southern Observatory, Casilla 19001, Santiago 19, Chile
[2] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D–5300 Bonn 1, Germany

We have observed 59 young stars associated with Herbig-Haro objects in the continuum at 1300 μm, and detected 53 of them, corresponding to the very high detection rate of 90%. The signals are generally large, of the order of several hundred milliJansky. High extinction sources have on average more than twice as large a flux as low extinction sources. Translating the 1300 μm measurements into total gas and dust masses, under appropriate assumptions, we find that Herbig-Haro energy sources are surrounded by considerable amounts of cold circumstellar material, typically in the range from a few tenths to several solar masses. We have additionally observed 14 sources at 870 μm, and derive a spectral index $m = 1.0 \pm 0.4$, assuming a typical dust temperature of 36 K, determined by additionally employing IRAS data. Such a spectral index suggests either the presence of grains larger than in the interstellar medium and/or material with large optical depth. A comparison with 1300 μm fluxes of T Tauri stars from the literature shows that T Tauri stars and Herbig-Haro energy sources have very different distributions in a histogram of fluxes scaled to a given distance: the Herbig-Haro energy sources have fluxes more than an order of magnitude larger than the T Tauri stars. From their IRAS energy distributions it follows that almost all Herbig-Haro energy sources are class I sources. The large difference observed between Herbig-Haro energy sources and T Tauri stars thus suggests that the major changes in the circumstellar environment of a young low mass star occurs within its first few hundred thousand years, which is a likely upper limit for the age of class I sources. We observe a clear relation between bolometric luminosity and 1300 μm flux for our objects, suggesting that the more massive a circumstellar environment is, the larger is the accretion rate towards the star likely to be.

Accepted by Astron. and Astrophys.

Star Formation in Bok Globules and Low-Mass Clouds. V. Hα Emission Stars near Sa 101, CG13 and CG22

Bo Reipurth[1] and Bertil Pettersson[2]

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

We have surveyed five fields in the Gum Nebula containing cometary globules, in a search for new regions of low-mass star formation. Seven Hα emission stars were found in association with the CG4/CG6/Sa101 cloud complex, and one in association with the CG13 globule. All eight stars are late type emission line stars, and appear to be low-mass pre-main sequence stars. Low dispersion spectra and optical and infrared photometry are presented for the objects, as well as for PHα 92, an already known young star in CG22. Most of the globules surveyed are not associated with Hα emission stars. We demonstrate that star formation has occurred in the Gum Nebula over several million years, right up to very recently.

Accepted by Astron. and Astrophys.

On the Nature of the Centimeter Continuum Emission from the FU Orionis Stars V1057 Cyg and Elias 1–12

Luis F. Rodríguez[1] **and Lee W. Hartmann**[2]

[1] Instituto de Astronomía – UNAM, Apdo. Postal 70–264, 04510 México D.F., México
[2] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

Using the Very Large Array we observed at 2 and 1.3-cm the FU Orionis stars V1057 Cyg and Elias 1–12. Both stars were detected as unresolved sources at 2-cm and upper limits for their flux densities were set at 1.3-cm. Our new results, combined with the published 3.6-cm flux densities, permit to establish that the emission from these stars in the centimeter wavelengths has a spectral index of ~ 0.7, characteristic of free-free emission from ionized outflows. The estimated ionized mass loss rates for both V1057 Cyg and Elias 1–12 are $\sim 10^{-7}$ $M_\odot$ yr^{-1}, much lower than the maximum mass loss rates observed from FU Orionis objects. In the case of V1057 Cyg, optical constraints suggest that the wind may be only about 10% ionized.

Accepted by Rev. Mex. Astron. Astrofis.

PIG Anatomy: Density and Temperature Structure of the Bright-Rimmed Globule IC 1396E

E. Serabyn[1], **R. Güsten**[1−2] **and L. Mundy**[3]

[1] California Institute of Technology, Pasadena, CA 91125, USA
[2] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 5300 Bonn 1, Germany
[3] University of Maryland, College Park, MD 20742, USA

The bright-rimmed cometary globule IC 1396E, centered roughly on IRAS 21391+5802, has been mapped in a number of molecular transitions in order to determine its density and temperature structure, and to asses the possibility that recent internal star-formation was triggered by the ionization front on its southern surface. Based on NH_3 data, gas temperatures in the globule are found to increase outward from the center, from a minimum of $T_K = 17$ K in its tail to a maximum of $T_K = 26$ K on the surface most directly facing the stars ionizing IC 1396. In contrast, the effects of heating by the embedded IRAS source are not discernable within the $40''$ beam, implying that the bulk of the globule is heated externally.

On the other hand, the density-sensitive CS emission is well correlated with the presence of the embedded IRAS source, peaking close to it in the four different rotational transitions observed. The spatial extent of the CS emission decreases with increasing rotational level, indicative of a steep radial density profile. Using a microturbulent radiative transfer code to model the radial dependence of the CS line intensities, and also the intensities of the optically thin $C^{34}S$ $J = 2-1$ and $5-4$ lines toward the cloud center, we find a radial density dependence of $r^{-1.55}$ to $r^{-1.75}$ extending out to a sharp cutoff at $r_{max} = 8(\pm1) \times 10^{17}$ cm^{-2}, beyond which no low density molecular envelope is present. This r_{max} matches the optical size of the globule very closely. Within r_{max}, the globule mass is $480 \pm 120 M_\odot$.

Because of the observed separation of the density peak from the ionization front, the steep density rise toward the center of the globule must predate the arrival of the ionization front. The high densities ($< n > \approx 10^5$ cm^{-3}) and internal turbulent pressures present indicate that the ionization front can have directly compressed only the outermost layers of the cloud, leaving the core density structure relatively unaffected. Thus, the globule had already been evolving toward collapse on its own. While the slight perturbation provided by the added pressure of the ionization front might be sufficient to induce such a core to collapse, spontaneous collapse is the most viable model for the evolution of this globule.

Accepted by Astrophys. J.

Accretion Disc Viscosity: A Simple Model for a Magnetic Dynamo

C. A. Tout[1] **and J. E. Pringle**[1−2]

[1] Institute of Astronomy, Madingley Road, Cambridge, CB3 OHA, United Kingdom
[2] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

We develop here a simple physical model for the manner in which a magnetic dynamo might operate in an accretion disc and so provide an effective (magnetic) viscosity. In contrast to other dynamo models, the mechanism we discuss does not depend on the existence of some hydrodynamical small-scale turbulent flow hypothesized to be already present in a non-magnetic disc. Rather, the model we present depends on three well-established physical processes: the Parker instability, the Balbus-Hawley instability and magnetic field reconnection. The model gives rise to finite but non-stationary magnetic field configurations. For the set of parameters chosen here we find a time-averaged effective viscosity with Shakura-Sunyaev α-parameter around $\alpha_{SS} \approx 0.4$.

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

Model Scattering Envelopes of Young Stellar Objects. II. Infalling Envelopes

Barbara A. Whitney and Lee Hartmann

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

We present scattered light images for models of young stellar objects surrounded by dusty envelopes. The envelopes are assumed to have finite angular momentum and are falling in steady flow onto a disk. The model envelopes include holes, such as might be created by energetic bipolar flows. We calculate images using the Monte Carlo method to follow the light scattered from the dusty envelope and circumstellar disk, assuming that the photons originate from the central source. Adopting typical interstellar medium dust opacities and expected mass infall rates for protostars $\dot{M} \sim 10^{-6} \, M_{\odot}$ yr^{-1}, we find that detectable amounts of optical radiation can escape from envelopes falling in to a disk as small as $\sim 10 - 100$ AU, depending upon the viewing angle and the size of the bipolar flow cavity. The models explain general features of polarization maps of many young stellar objects. In particular, parallel polarization patterns ("polarization disks") can be produced by multiple scattering effects very simply in envelopes and do not require large-scale disk structure. We suggest that the extended optical and near-infrared light observed around several young stars is scattered by dusty infalling envelopes rather than disks.

Accepted by Astrophys. J.

Meetings

Kinematics and Dynamics of Diffuse Astrophysical Media
A Conference in honour of Professor F.D. Kahn

Dates: 22 – 26 March 1993

Venue: De partment of Astronomy, The University, Manchester, U.K.

Covering Observational and Theoretical Aspects of
* Interstellar and Circumstellar Gas Dynamics
* Galactic Scale Flows
* Flows in Active Galaxies and QSOs

Speakers will include:
D. Axon, B. Balick, J. Cantó, Y-H Chu, J. Drew, S. Falle, T. Hartquist, J. Meaburn, J. Perry, A. Raga, T. Ray, J. Raymond, H. Van de Hulst, L. Woltjer.

The scientific sessions will contain reviews, contributed papers and poster papers.
The proceedings of the meeting will be published.
Modestly priced accommodation will be available in a University Hall of Residence.

For further information, proposals for contributed papers etc.
Contact: John Dyson. Tel: (061) 275 4235. JED@UK.AC.MAN.AST.STAR
or Mrs. Ellen Carling, Tel: (061) 275 4224. EBC@UK.AC.MAN.AST.STAR
Fax: (061) 273 5867

Books

Low Mass Star Formation in Southern Molecular Clouds
ESO Scientific Report No. 11, 211 pages.

Contents: Low Mass Star Formation in Orion (J. Brand and J.G.A. Wouterloot), The Canis Majoris OB1 Association (G.H. Herbig), Low Mass Star Formation in Puppis and Vela (B. Pettersson), The Chamaeleon Dark Clouds and T-Associations (R.D. Schwartz), The Southern Coalsack – Where are all the Young Stars? (L.-Å Nyman), The Star Forming Region in Lupus (J. Krautter), Young Low Mass Stars in the Norma Cloud (B. Reipurth and J.A. Graham), Star Formation in the Ophiuchus Molecular Cloud Complex (B.A. Wilking), Star Formation in the Corona Australis Region (J.A. Graham), The Serpens Molecular Cloud (C. Eiroa).

The book gives an overview of each of the most important southern regions of low mass star formation. It is available for researchers working in the field of star formation, free of charge as long as stock permits, by writing to

ESO Information Service
Karl-Schwarzschild-st 2
D–8046 Garching bei München
Germany