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From the Editor

We have recently restructured our computer network at ESO/Chile, and this has on some occasions led to problems with mail. If you have sent an abstract which does not appear in the newsletter, please send it again.

In its slightly more than 2 years of existence, the Star Formation Newsletter has grown considerably, and is now reaching almost 600 persons all over the world. It has thus achieved its goal of becoming a vehicle for linking the star formation community closer together. You are encouraged to use the various sections in the newsletter. For example, many students and postdocs receive the newsletter, and if you have a position open which is specifically aimed towards persons working in star formation, molecular clouds and the interstellar medium, you are welcome to advertise here (more general job adds should be sent to the usual places). If you have recently finished your thesis in one of the fields of the newsletter, or know of someone who has, an abstract in the newsletter will bring your work to the attention of the entire community. Simple latex forms for both normal abstracts and dissertation abstracts are appended to each newsletter after the enddocument command.

Merry Christmas and a happy New Year to everybody.

Bo Reipurth

Abstracts of recently accepted papers

Multiple Star Formation In Bok Globule CB34

João Alves[1], and João Lin Yun[1]

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

As part of a deep near-infrared imaging survey for infrared point sources in Bok globules, we have discovered the first Bok globule showing evidence of harboring an aggregate of embedded objects.

Using a near-infrared color-color diagram, a total of 12 objects seen towards this globule were found to exhibit near-infrared color excesses consistent with those of young stellar objects having intrinsic infrared excess emission due to circumstellar material. Four of these objects exhibit extended infrared emission similar to those seen surrounding other young stellar objects in Bok globules.

The objects are contained in a region of about 3 arcmin^2 estimated to correspond to about 0.1 pc^2.

Together, these facts indicate that this group of stars forms an aggregate of young stellar objects contained in the globule.

Accepted by The Astrophysical Journal Letters

Spectral Energy of First Protostellar Cores: Detecting "Class -I" Protostars with *ISO* and *SIRTF*

Alan P. Boss[1] **and Harold W. Yorke**[2]

[1] DTM, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015, USA

[2] Astronomisches Institut, Universität Würzburg, am Hubland, D-97074 Würzburg, FRG

Radiative hydrodynamical models of protostellar collapse are used to calculate the spectral energy distributions of single and binary protostars at the phase of formation of the first (outer) protostellar core. In accordance with the established nomenclature, where classes 0, I, II, and III form a sequence in time, we term these pre-class 0 objects to be class -I ("class minus one") objects. These class -I objects are characterized by central core temperatures of ~ 200 K, envelope temperatures of ~ 10 K, and substantial far-infrared and submillimeter-wave fluxes. While undetectable by *IRAS*, these objects should be detectable by *ISO* and *SIRTF* at 60 μm and longer wavelengths. First protostellar cores exist for times on the order of a few percent of the total collapse time, implying that a small fraction of all protostellar objects should be class -I objects.

Accepted by Astrophysical Journal (Letters)

COYOTES II: spot properties and the origin of photometric period variations in T Tauri stars

J. Bouvier[1], **E. Covino**[2], **O. Kovo** [3], **E.L. Martín** [4], **J.M. Matthews** [5], **L. Terranegra** [2], **and S.C. Beck**[3]

[1] Laboratoire d'Astrophysique, Observatoire de Grenoble, Université Joseph Fourier, B.P. 53X, 38041 Grenoble Cedex, France,bouvier@gag.observ-gr.fr

[2] Osservatorio Astronomico di Capodimonte, Via Moiariello 16, I-80131 Napoli, Italy

[3] School of Physics and Astronomy, Tel Aviv University, Ramat Aviv, 69978, Israel

[4] Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain

[5] Department of Geophysics and Astronomy, University of British Columbia, Vancouver, B.C., V6T1Z4, Canada

We present the results of a new multi-site campaign (COYOTES II) to monitor the light variations of T Tauri stars (TTS) of the Taurus-Auriga dark cloud. The UBVRI light curves of 19 TTS were obtained over a two months period to search for rotational modulation by spots. We report new period detections for IQ Tau (6.25d), LkCa-3 (7.2d), and LkCa-14 (3.35d) and confirm previously detected periods for DF Tau (9.8d), DR Tau (9.0d), GM Aur (11.9d), and TAP 26 (2.58d). We also report tentative periods for CW Tau (8.2d), CY Tau (7.9d), HP Tau (5.9d), and XZ Tau (2.6d). No periods were found in the present data set for CI Tau, DG Tau, DQ Tau, GH Tau, RY Tau, Hubble 4, TAP 45, and TAP 57NW.

Altogether, the results of this new campaign confirm the main conclusion of COYOTES I that classical T Tauri stars (CTTS) on average have longer rotational periods than weak-line TTS (WTTS). The present study also confirms that rotational modulation in WTTS is due to spots cooler than the photosphere and we show that the amplitude of the modulation primarily reflects the amount of areal coverage by spots. The amplitude of the light variations, and hence the spot size, is found to increase with both rotation rate and advancing spectral type, as expected if WTTS cool spots correspond to photospheric regions of strong dynamo-generated magnetic fields. Finally, combined with previous studies, these new results provide further evidence for temporal variations of the photometric periods of CTTS. Such variations seem to occur preferentially in CTTS whose rotational modulation is dominated by hot spots and we therefore argue that the observed period changes are linked to the magnetospheric accretion process rather than to surface differential rotation.

Accepted by Astron. Astrophys., Main Journal

Low-mass star formation in CG1: a diffraction limited search for pre-main sequence stars next to NX Puppis

Wolfgang Brandner[1,2], **Jerome Bouvier**[3], **Eva K. Grebel**[4], **Eric Tessier**[5], **Dolf de Winter**[6], **and Jean-Luc Beuzit**[7]

[1] Astronomisches Institut der Universität Würzburg, Am Hubland, D-97074 Würzburg

[2] European Southern Observatory, Casilla 19001, Santiago 19, Chile

[3] Laboratoire d'Astrophysique, Observatoire de Grenoble, Université J. Fourier, B.P. 53, F-38041 Grenoble Cedex 9, France
[4] Sternwarte der Universität Bonn, Auf dem Hügel 71, D-53121 Bonn, Germany
[5] Royal Greenwich Observatory, Madingley Road, Cambridge CB3 0EZ, England
[6] Astronomisch Instituut "Anton Pannekoek", University of Amsterdam, Kruislaan 403, NL-1098 SJ Amsterdam, The Netherlands
[7] Observatoire de Paris, DESPA (URA 264/CNRS), 5 place Jules Janssen, F-92195 Meudon, France

E-mail contact: brandner@astro.uni-wuerzburg.de

Using adaptive optics at the ESO 3.6m telescope, we obtained diffraction limited JHK-images of the region around the Herbig AeBe star NX Pup. We clearly resolved the close companion (sep. 0.128″) to NX Pup – originally discovered by HST – and measured its JHK magnitudes. A third object at a separation of 7″ from NX Pup was identified as a classical T Tauri star so that NX Pup may in fact form a hierarchical triple system. We discuss the evolutionary status of these stars and derive estimates for their spectral types, luminosities, masses and ages.

Accepted by Astronomy and Astrophysics; preprints are available from Wolfgang Brandner

Anatomy of the Gem OB1 Molecular Cloud Complex

John M. Carpenter[1,2], Ronald L. Snell[1], & F. Peter Schloerb[1]

[1] Department of Physics and Astronomy, University of Massachusetts, Amherst, MA 01003, USA

[2] Institute for Astronomy, Univ. of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96821, USA; carp@galileo.ifa.hawaii.edu

We have investigated the large scale morphology and properties of the molecular gas in the Gem OB1 cloud complex by mapping over 32 deg^2 (177 pc x 222 pc) of the complex in ^{12}CO(J=1–0) and ^{13}CO(J=1–0) at 50″ sampling with QUARRY on the FCRAO 14 m telescope. The most striking characteristic of the molecular line images are the series of arcs and rings shaped structures found on spatial scales from a few parsecs in diameter up to at least 35 pc. The morphology and in some instances the kinematics suggest that these features represent swept up molecular material, most likely from expanding HII regions and wind blown bubbles. The kinetic temperatures and column densities of the molecular gas were derived from the ^{12}CO and ^{13}CO data using the LTE analysis. Most of the molecular gas was found to have kinetic temperatures of $\leq$ 10 K, and 50% of the mass of gas is contained in lines of sight with H_2 column densities $\leq$ 3 x 10^{21} cm^{-2}. It was found that only 17% of the molecular mass is contained in lines of sight with column densities in excess of 10^{22} cm^{-2}, and that these regions are found almost exclusively near the massive star forming regions within the arcs and rings of molecular gas. The average H_2 densities in areas with ^{13}CO emission are between 95–176 cm^{-3}, consistent with previous studies of cloud complexes, and is independent of whether the regions contains massive star formation or not. For the Gem OB1 complex as a whole, the average H_2 density is 1.6 cm^{-3}, which is only a few times the average atomic hydrogen density in the interstellar medium.

We suggest a overall picture for the Gem OB1 complex in which most of the molecular gas is contained in relatively cold, low column density molecular material. The high column density regions in the Gem OB1 complex form through the external compression of the molecular gas by the winds and HII regions from newly formed massive stars. Thus once massive star formation is initiated, the structure and further evolution of the cloud complex is largely a result of the interactions of expanding HII regions and stellar winds with the ambient molecular material.

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Bolometric Temperature and Young Stars in the Taurus and Ophiuchus Complexes

H. Chen[1], P. C. Myers[1], E. F. Ladd[2], and D. O. S. Wood[3]

[1] Center for Astrophysics, 60 Garden St. MS-42, Cambridge, MA 02138, USA
[2] FCRAO, University of Massachusetts, Amherst, MA 01003, USA
[3] National Radio Astronomy Observatory, Socorro, NM 87801, USA

We calculated bolometric temperature (T_{bol}) and luminosity (L_{bol}) for 128 young stellar objects (YSOs) in Taurus, 74 in the Ophiuchus "core", and 33 in the Ophiuchus "off-core" region. We have constructed the bolometric luminosity-temperature (BLT) diagram, the log-log plot of L_{bol} vs. T_{bol}, for the three samples. T_{bol} is defined as the temperature of a blackbody having the same mean frequency as the observed continuum spectrum. It measures the redness (or

coldness) of an astronomical source. The BLT diagram is analogous to the HR diagram and allows for a direct and quantitative comparison of YSOs at a wide variety of evolutionary states, ranging from the most deeply embedded stars to T Tauri stars nearly on the main sequence. We found (1) T_{bol} increases monotonically from embedded sources ($\sim 60-500K$) to classical T Tauri stars ($\sim 1000-3000K$) to weak-line T Tauri stars ($\sim 2000-5000K$); (2) T_{bol} correlates reasonably well with the age inferred from the evolutionary models of pre-main-sequence stars and protostars for embedded "protostars" and weak-line T Tauri stars. There is no significant correlation for the classical T Tauri stars. These results can be understood in terms of dissipation of circumstellar dust envelope and disk during the early stages of stellar evolution. Sources in the three regions have different distributions in the BLT diagram. The Ophiuchus core has the highest fraction of cold sources among the three regions. These cold sources are also more luminous than the YSOs in the other regions. The Ophiuchus off-core sample is dominated by the more evolved pre-main-sequence stars. The Taurus sources have distributions intermediate in L_{bol}, T_{bol}, and age between the Ophiuchus core and off-core distributions. These may suggest differences in the star formation history, and possibly in the stellar masses and mass accretion rates in these star-forming regions.

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Water Masers in the L1448C Outflow

Lawrence Chernin[1]

[1] Dept of Astronomy, Univ. of California, Berkeley CA 94720, USA

E-mail contact: chernin@astron.berkeley.edu

We have detected strong, highly variable 22.3 GHz water maser emission from the deeply embedded L1448C low mass protostar. The total maser intensity on 7/5/93 was 210 Jy km s^{-1} (6×10^{-7} L$_\odot$), which is two orders of magnitude more than that expected from a protostar with a bolometric luminosity of only 9 L$_\odot$.

The maser kinematics can not be fit with a disk model. Moreover, the L1448C maser spots are perfectly aligned with the collimated molecular outflow. Therefore we have found the first direct evidence for a connection between a water maser outflow and a molecular outflow.

The closest maser spots on either side of the source are separated by only 62 au. Thus the wind that originates from the protostar or disk must be collimated into a dense ($\approx 10^6$ cm^{-3}) jet within 31 au of the protostar.

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A copy of the paper is available via the internet http://ral.berkeley.edu:8000/home.html.

The Hα environment of T Tauri resolved by speckle interferometry

M.N. Devaney [1,2] E. Thiébaut [2,5], R. Foy [2,5], A. Blazit [3], D. Bonneau [3], J. Bouvier [4], B. de Batz [2], Ch. Thom [6]

[1] Instituto de Astrofisica de Canarias, Tenerife, Spain
[2] Observatoire de Paris-Meudon, Département DASGAL, CNRS URA 335, France
[3] Observatoire de la Côte d'Azur, Département A. Fresnel, CNRS URA 1361, France
[4] Observatoire de Grenoble, CNRS URA 708, France
[5] Observatoire de Lyon, CNRS URA 300, France
[6] Institut Géographique National, LOEMI, France

T Tauri, the prototype of a class of low-mass pre-main sequence stars, was observed with the 3.6m Canada-France-Hawaii telescope (CFHT) and the CP40 photon-counting camera in November 1989. The data have been analysed using techniques of Speckle Interferometry to obtain diffraction-limited information on the spatial extent of T Tauri in narrow passbands centered on the Hα line and the nearby red continuum. The object appears unresolved in the continuum passband, while it is resolved in Hα. The Hα emission is fitted with a model consisting of two strongly flattened two-dimensional gaussians. In this model $\approx$80% of the flux lies in a component (A) which is only marginally resolved, and $\approx$20% lies in a component (B) with a semi-major axis FWHM of $\approx$0."09. After substraction of continuum, 2/3 of the Hα emission is spatially unresolved and 1/3 is resolved. The position angle of component B is $192^o\pm5^o$ (modulo 180^o), which approximates the direction of the perpendicular to the jet known in the [OI] and [SII] lines; this jet extends 30" westwards up to the Herbig-Haro object HH1555. The corresponding linear size of the Hα emitting

region B is $\sim$ 6 by 15 AU FWHM assuming a distance of T Tauri of d=140pc. We argue that this emission arises either from the interaction between a weakly collimated wind with a circumstellar flaring disc, or from the basis of the westward jet which is seen on a larger scale.

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Star formation in L 1287 Main: The H_2O maser

D. Fiebig

Institut für Theoretische Astrophysik, Universität Heidelberg, Im Neuenheimer Feld 561, 69120 Heidelberg, Germany

Observations of the H_2O maser associated with the far infrared point source IRAS 00338+6312 are presented. The H_2O maser emission can be assigned to an unresolved source, which is located at the *formal* position of IRAS 00338+6312. Evidence that the central source responsible for the maser emission is a young stellar object located within 0.2 arcsec of the maser position comes from near infrared polarimetry and VLA radio continuum observations. It is suggested that this object is the driving source of the associated bipolar molecular outflow, and is responsible for the maser and the far infrared emission detected by IRAS, contrary to former investigations assigning these signs of star formation to the closeby FU Orionis stars RNO 1B and RNO 1C. Associated 18 cm OH maser emission could not be detected.

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A Near-infrared Reflection Nebula Associated with NGC 2024 FIR4

T.J.T. Moore[1] & T. Yamashita[2]

[1] Physics Department, University College, University of New South Wales, ADFA, Canberra, ACT 2600, Australia (email: tjm@phadfa.ph.adfa.oz.au)
[2] Okayama Astrophysical Observatory, Kamogata-chyo, Asakuchi-gun Okayama 719–02, Japan

H, K and 3.6-μm imaging observations at the location of the protostellar candidate NGC 2024 FIR4 confirm the presence of a highly reddened near-infrared source with estimated luminosity $\sim$25Ł$_\odot$ at the position of the submillimeter continuum core. Polarimetry at H and K shows that this source is accompanied by a compact cometary reflection nebula of the type associated with collimated molecular outflows from young stellar objects. These results enable the classification of NGC 2024 FIR4 as a low-mass, self-luminous, young stellar object producing an energetic outflow which is beginning to clear the ambient dense gas.

The details of the observed polarization vector pattern at H and K suggest the superposition of an extended polarization field which distorts the scattering pattern in the reflection nebula from centro-symmetry. It is likely that this additional field is produced by dichroic absorption through a foreground screen of dust grains aligned by an ordered magnetic field with projected orientation close to p.a. = 0^o.

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Evidence for Dust Around Post T Tauri Stars

T.P. Ray[1], A.I. Sargent[2], S.V.W. Beckwith[3], C. Koresko[4], and P. Kelly[1]

[1] School of Cosmic Physics, Dublin Inst. for Adv. Studies, 5 Merrion Square, Dublin 2, Ireland
[2] Division of Physics, Mathematics and Astronomy, California Institute of Technology, USA
[3] Max Planck Institute for Astronomy, Heidelberg, Germany
[4] Department of Astronomy, University of Texas at Austin, USA

E-mail for preprint requests: tr@cp.dias.ie

Post T Tauri stars are young stars which, although older than classical T Tauri stars, have not yet reached the main sequence. We report the detection of a far-infrared excess in binary systems consisting of a post T Tauri secondary and a B-type primary. Assuming this excess arises from dust surrounding the secondary, it is not clear whether the primary or the secondary, i.e. the post T Tauri star, is the dominant heating source. We searched for continuum 1.1 mm emission in a small sample of candidate (or confirmed) post T Tauri and post Herbig Ae/Be stars with the Caltech Submillimeter Observatory. In no case did we detect any emission. The inferred upper limits to the amount of dust present is typically one or two orders of magnitude lower than that found around classical T Tauri/Herbig

Ae/Be stars suggesting rapid evolution of the disk before a star reaches the post T Tauri/Herbig Ae/Be phase.

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A Lunar Occultation and Direct Imaging Survey of Multiplicity in the Ophiuchus and Taurus Star Forming Regions†

M. Simon[1], A.M. Ghez[2,3], Ch. Leinert[4], L. Cassar[5], W.P. Chen[6], R.R. Howell[7], R.F. Jameson[8], K. Matthews[3], G. Neugebauer[3], and A. Richichi[4]

[1] Astronomy Program, State Univ. of New York, Stony Brook, NY 11794, USA
[2] Dept. of Astronomy, Univ. of California, Los Angeles, CA 90024, USA
[3] Palomar Obs., California Institute of Technology, Pasadena, CA 91125, USA
[4] Max-Planck-Institut für Astronomie, Königstuhl 17, D- 69117 Heidelberg, Germany
[5] Dept. of Mathematics and Science, U.S. Merchant Marine Academy, Kings Point, NY 11024, USA
[6] Institute of Astronomy and Dept. of Physics, National Central University, 32054 Chung-Li, Taiwan
[7] Physics & Astronomy Dept., Univ. of Wyoming, Box 3905, University Station, Laramie, WY 82071, USA
[8] Astronomy Group, University of Leicester, University Rd., Leicester LE1 7RH, England

† From our first contact, through the observations of 1991 and a rained-out attempt in 1992, David Allen did his best to make the AAT observations a success. It was characteristic that he asked, in May, 1994, that he not appear as a coauthor. David Allen died on July 26, 1994. We dedicate the paper to his memory.

E-mail contact: msimon@sbast1.ess.sunysb.edu

We present an IR lunar occultation and direct imaging search for companions in the Ophiuchus star forming region and update a similar search of the Taurus region. The search is sensitive to companions in the angular separation range 0.005 to 10″. In Ophiuchus we surveyed 35 young star targets; this sample contains at least 10 binaries, 2 triples, and one quadruple. Ten of the companion stars are newly discovered. In Taurus, the survey now includes 47 systems among which there are at least 22 binaries and 4 triples. Only 2 companion stars are newly identified because there is strong overlap with prior work. All the triples and quadruple are hierarchical. The observed binary frequency in Ophiuchus, in the 3 to 1400 AU range of separations, is *at least* 1.1 ± 0.3 that of the nearby solarlike stars. This value is a lower bound because we make no corrections for incompleteness. In Taurus, in the same range of separations, the observed binary frequency is *at least* 1.6 ± 0.3 that of the nearby solarlike stars. This value extends Ghez *et al.*'s (1993) and Leinert's *et al.*'s (1993) determination of an excess binary frequency to 3 AU separation. We used the WT/TT type and the K-L color index to distinguish between systems with and without inner disks. We find no convincing difference in the binary frequency or distribution of separations of the systems with and without inner disks. The 1.3 mm continuum emission of the single systems exceeds that of the multiples suggesting that their extensive outer disks are more massive. The specific angular momenta of the binaries overlap those of molecular cloud cores measured by Goodman *et al.* (1993).

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Predictions for JHK Photometry of Molecular Shocks

Michael D. Smith

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

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

Near-infrared photometry in the J, H and K bands is increasingly employed to identify young stars, still deeply embedded. But when can a star be reliably differentiated from a shock? The infrared colours of molecular shocks are calculated here, summing over the many contributing lines of vibrationally-excited molecular hydrogen, combined with appropriate filters, reddening and fast-shock iron-line emission. Simulated spectral templates are also presented from which lines and bands useful as diagnostics are specified.

The intrinsic infrared colours of shocks are easily recognised with a particularly faint H-band. Embedded (reddened) shocks, however, possess similar colours to extreme Class I sources. It is concluded that for strong 'infrared-excess' sources the colour-colour diagram alone does not provide sufficient information to exclude a shock.

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The spatial distribution of X-ray selected T-Tauri stars: I. Orion

Michael F. Sterzik[1], Juan M. Alcalá[1,2], Ralph Neuhäuser[1] and J.H.M.M. Schmitt[1]

[1] Max Planck Institut für extraterrestrische Physik, 85740 Garching bei München, Germany
internet: sterzik@mpe-garching.mpg.de
[2] Instituto Nacional de Astrofisica Optica y Electrónica, C.P. 72000 Puebla, México

We establish a criterion for selecting low-mass, pre-main sequence star candidates from X-ray sources discovered in the ROSAT All-Sky Survey. X-ray properties and non-spectroscopic data (hardness ratios and X-ray to optical flux ratio) of 187 optically identified X-ray sources in the Orion star forming region are used as a training set for a non-parametric discrimination analysis. We show that high selection reliabilities of weak-line T-Tauri stars (wTTS) can be obtained with this method. We utilize the selection procedure to predict the large scale spatial distribution of TTS candidates in a 710 deg^2 field around the Orion SFR. Five significant surface density enhancements are identified, four of them are well matched with OB subgroup associations (OB1a, λ-Ori, OB1b, OB1c). A dispersion time of 2-10 Myr can be derived from their spatial extent, consistent with the ages of the stellar component in these regions. We suspect a young stellar cluster in the vicinity of NGC 1788, where a high concentration of TTS candidates resides. The largest fraction of the predicted wTTS population is distributed widely over an area many times greater than that of the molecular gas. If these sources really are wTTS, they must be either much older than usually assumed or have a high velocity dispersion.

Accepted by A.&A.

IRAS Sources beyond the Solar Circle. VI. Analysis of the FIR, H_2O, and CO Emission.

J.G.A. Wouterloot[1], K. Fiegle[1], J. Brand[2], and G. Winnewisser[1]

[1] I. Physikalisches Institut, Zülpicher Strasse 77, D-50937 Köln, Germany
[2] Istituto di Radioastronomia, CNR, Via Gobetti 101, I-40129 Bologna, Italy

For a sample of 1357 IRAS sources with FIR colours of Young Stellar Objects we have compared the occurrence and properties of H_2O maser- and ^{12}CO(1-0) emission with the observed and derived IRAS parameters.
We find that the distribution of differences between the CO and H_2O velocities is a Gaussian with a FWHM of about 11 kms^{-1}. The mean velocity difference is nearly zero. The velocity of the peak H_2O emission is not at a preferred location within the velocity interval where emission is detected.
The H_2O maser detection rate increases with both the FIR luminosity and the ^{12}CO(1-0) line width: below $\log(L_{FIR}/L_\odot)$=3.5, less than 10% of the sources show maser emission, whereas H_2O is detected towards almost all of the sources above $\log(L_{FIR}/L_\odot)$=4.5. For the sources with H_2O maser emission, the average CO line width (FWHM about 5.0 kms^{-1}) is approximately twice as large as for those without detected H_2O emission, an effect which is independent of the sources' FIR luminosity. However a significant fraction of sources with no detected H_2O emission still have line widths larger than 1.9 kms^{-1}, the median value for the quiescent gas not associated with the IRAS sources. The maximum H_2O maser luminosity found at each FIR luminosity is proportional to L_{FIR}: $L_{H_2O}/L_\odot = 10^{-7.4}(L_{FIR}/L_\odot)$.
In IRAS colour-colour plots, sources can be distinguished in maser-like and non-maser-like sources according to their CO line widths and FIR luminosity. At a given L_{FIR} the maximum T_A^* found for ^{12}CO(1-0) decreases with distance from the Sun, likely due to beam filling effects. Few sources with maser emission have T_A^* below 7.5 K, when observed with the IRAM 30-m telescope. There is no difference in the maximum T_A^* of sources with maser-like and non-maser-like IRAS colours.
We have derived the intrinsic luminosity- and mass distribution of sources with (non)-maser-like IRAS colours, correcting for incompleteness effects at lower luminosities. The slope of the IMF for sources with maser-like colours and mass larger than 10 $M_\odot$ is found to be -2.8 ± 0.3.

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Dissertation Abstracts

Magnetized Accretion-Ejection Structures

Jonathan Ferreira

Thesis work conducted at: Laboratoire d'Astrophysique, Observatoire de Grenoble, France

Current address: Landessternwarte, Königstuhl, 69117 Heidelberg, Germany

Electronic mail: jferreir@mail.lsw.uni-heidelberg.de

Ph.D dissertation directed by: Guy Pelletier

Ph.D degree awarded: September 1994

For both active galactic nuclei (AGN) and young stellar objects (YSO), the common belief is growing that there is an interdependency between accretion of mass onto a central object and the highly collimated jets. This thesis deals with the investigation of the physical mechanism that leads to the formation of jets from a magnetized accretion disk. This has been done by solving the set of magnetohydrodynamical (MHD) equations in the case of an isothermal disk, using a self-similar approach. All the dynamical terms are included, so that the main results are independant of the modelling and thus, completely general. Indeed, a different temperature vertical profile only slightly modifies the parameters required for stationarity.

A resistive thin accretion disk is thread by open magnetic field lines, sheared by its differential rotation. The field lines brake the disk and extract both angular momentum and mechanical energy from it. Because of the large magnetic "lever arm" acting on the disk, the magnetic braking is always dominant and the viscous torque is negligible. An equipartition magnetic field is enough, without significantly perturbing the Keplerian rotation. Thus, jets carry away all the angular momentum of the underlying accretion disk.

Steady state accretion is achieved in the disk due to an anomalous magnetic diffusivity that allows the matter to slip across the field lines. This anomalous transport coefficient should arise from the saturation of a strong magnetic instability triggered in the disk. Ambipolar diffusion, which could have been used without losing the generality of the present results, remains however smaller than this anomalous diffusivity in the inner parts of a circumstellar disk.

It has been found that steady state ejection can be achieved only if the magnetic torque changes its sign at the disk surface. From this point on, the field lines accelerate azimuthaly the matter transfering it both angular momentum and energy. This requires a balance between the differential rotation effect (that tends to provide a negative radial current inside the disk) and the "Barlow Wheel" effect (that gives rise to a positive radial current at the disk midplane, hence allowing magnetic braking), leading to the decrease on a disk scale height of the radial current. This means that the field lines are less sheared as one goes upwards to the disk surface.

A natural transition between the accretion disk and the jet arises because, as the radial current decreases vertically, the vertical magnetic compression drops and the plasma pressure gradient gives rise to an ascendant motion. Thus, it is the plasma pressure that first drives ejection. The magnetic tension forces then the plasma to be ejected outwardly, being then more and more attached to the poloidal field lines. In the ideal MHD region above the disk, the jet velocity becomes super slow-magnetosonic (first critical point encountered by the flow) and increases due to both magnetic and centrifugal forces.

The overall structure is complex, with an equipartition between magnetic and thermal energy densities as well as components of the magnetic field of the same order of magnitude at the disk surface. The full parameter space of such a structure will be fixed by two additional regularity conditions, at the Alfvénic and fast magnetosonic critical points of the jet.

We derive, for both AGN and YSO, the observational signatures of optically thick MHD disks driving jets, as well as the global energy budget and its consequences on jets.

A Study of the Kinematics of the Local Dark Clouds

B.Ramesh

Thesis work conducted at: Raman Research Institute, under the Joint Astronomy Program, Department of Physics, Indian Institute of Science, Bangalore, India 560012

Current address: Raman Research Institute, C.V.Raman Avenue, Sadashivanagar, Bangalore, India 560080.

Electronic mail: bram@rri.ernet.in

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Lack of reliable estimates of distances to most of the local dark clouds has, so far, prevented a quantitative study of their kinematics. Using a statistical approach, we have been able to extract the average spatial distribution as well as the kinematical behaviour of the local dark clouds from their measured radial velocities. Since radial velocities were available only for the northern dark clouds, we have obtained them for 115 southern ones to make a more complete kinematical study of the local clouds. The thesis mainly deals with the presentation of this new data, analysis of the new as well as the existing data and the comparison of the results with those arrived at by earlier studies.

The local clouds are found to be expanding at a speed of ~ 4 kms^{-1} which is in general agreement with the estimates from optical and HI studies. However, it is found that the kinematics of the local clouds is not described by the model proposed for the local HI gas where a ring of gas expanding from a point gets only sheared by the galactic rotation. Rather, the observed distribution of their radial velocities is best understood in terms of a model in which the local clouds are participating in circular rotation appropriate to their present positions with a small expansion also super-imposed. This possibly implies that cloud-cloud collisions are important. The spatial distribution of clouds derived using such a model is in good agreement with the local dust distribution obtained from measurements of reddening and extinction towards nearby stars. In particular, a region of size $\sim$ 350pc in diameter enclosing the Sun is found to be devoid of clouds. Intriguingly, most clouds in the longitude range 100° to 145° appear to have negative radial velocities implying that they are approaching us.

Two other related research efforts are also reported in the thesis: (i) Since the clouds observed are distributed over the entire longitude range and wide latitude range, the resultant database of the spectral line parameters is well suited for studying the average physical properties of the local clouds. Our investigation in this regard shows that, with respect to latitude, the medians of both the brightness temperatures of the clouds and their ^{13}CO column densities increase marginally while the median of the ^{12}CO linewidths shows clear decrease. Some explanations for these trends are given. (ii) Maps of one of the Orion system of cometary clouds, L1616, in J=1→0 transitions of ^{12}CO and ^{13}CO are also presented. The distribution of the "wing" emission shows evidence for mass motions. Also, the "virial" mass of the cloud is found to be five times the actual cloud mass determined from the ^{13}CO column density map. It is argued that this cloud has abnormal star formation efficiency and is possibly disintegrating. The morphology and the location of the cloud indicates that it is being affected by the star ϵ Orionis which is also possibly responsible for the cloud's unusual star formation efficiency.

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