# THE STAR FORMATION NEWSLETTER

*An electronic publication dedicated to early stellar evolution and molecular clouds*

No. 121 — 12 November 2002 Editor: Bo Reipurth (reipurth@ifa.hawaii.edu)

*Abstracts of recently accepted papers*

## X-Rays from the Vicinity of the Protostar L1551 IRS 5: Reflection or Fast Shocks?

**John Bally[1], Eric Feigelson[2] and Bo Reipurth[3]**

[1] Center for Astrophysics and Space Astronomy, University of Colorado, CB 389, Boulder, CO 80309, USA
[2] Department of Astronomy & Astrophysics, Pennsylvania State University, 525 Davey Laboratory, University Park, PA 16802, USA
[3] Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA

E-mail contact: bally@casa.colorado.edu

We present new Chandra X-ray Observatory observations of the L1551 molecular cloud in Taurus. We find a compact, but slightly resolved X-ray source, displaced westward from the IRS 5 binary protostar by about 50 to 100 AU, which coincides with the base of the HH 154 protostellar jet. The column density of material lying in front of the X-ray source is more than an order of magnitude lower than the column density towards L1551 IRS 5. Thus, it is highly improbable that the X-rays come directly from the embedded proto-binary. It is possible, however, that X-rays produced by one or both members of the IRS 5 binary escape through the outflow cavity and are scattered into the line of sight by a dense infalling envelope or material in the outflow. Constraints on the physical properties of the scattering medium are discussed. It is also possible that the X-rays are produced in-situ by fast shocks at the base of the HH 154 jet. We consider several possible geometries for such shocks. The radiating plasma may be located behind standing shocks where a wide-angle wind from one member of the IRS 5 binary is collimated into a jet, or behind shocks formed on the axis of the outflow where winds from each member of the binary collide, or where these winds impact a tilted circumbinary disk. To produce the observed X-ray luminosity and plasma temperature, shock velocities larger than 350 km $s^{-1}$ are required with a pre-shock hydrogen density of $1 - 5 \times 10^3$ $cm^{-3}$. The implied post-shock cooling length is around 800 AU, close to the observed length of the bright near-infrared [Fe II] emission in the inner portion of the HH 154 jet.

Accepted by Astrophys. J.

## The Formation of a Star Cluster: Predicting the Properties of Stars and Brown Dwarfs

**Matthew R. Bate[1,2], Ian A. Bonnell[3], and Volker Bromm[2,4]**

[1] School of Physics, University of Exeter, Stocker Road, Exeter EX4 4QL, United Kingdom
[2] Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, United Kingdom
[3] School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews, Fife, KY16 9SS, United Kingdom
[4] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, U.S.A.

E-mail contact: mbate@astro.ex.ac.uk

We present results from the largest numerical simulation of star formation to resolve the fragmentation process down to the opacity limit. The simulation follows the collapse and fragmentation of a large-scale turbulent molecular cloud to form a stellar cluster and, simultaneously, the formation of circumstellar discs and binary stars. This large range of scales enables us to predict a wide variety of stellar properties for comparison with observations.

The calculation clearly demonstrates that star formation is a highly-dynamic and chaotic process. Star formation occurs in localised bursts within the cloud via the fragmentation both of dense molecular cloud cores and of massive circumstellar discs. Star-disc encounters form binaries and truncate discs. Stellar encounters disrupt bound multiple systems. We find that the observed statistical properties of stars are a natural consequence of star formation in such a dynamical environment. The cloud produces roughly equal numbers of stars and brown dwarfs, with masses down to the opacity limit for fragmentation ($\approx 5$ Jupiter masses). The initial mass function is consistent with a Salpeter slope ($\Gamma = -1.35$) above 0.5 $M_\odot$, a roughly flat distribution ($\Gamma = 0$) in the range $0.006 - 0.5$ $M_\odot$, and a sharp cutoff below $\approx 0.005$ $M_\odot$. This is consistent with recent observational surveys. The brown dwarfs form by the dynamical ejection of low-mass fragments from dynamically unstable multiple systems before the fragments have been able to accrete to stellar masses. Close binary systems (with separations $\lesssim 10$ AU) are not formed by fragmentation in situ. Rather, they are produced by hardening of initially wider multiple systems through a combination of dynamical encounters, gas accretion, and/or the interaction with circumbinary and circumtriple discs. Finally, we find that the majority of circumstellar discs have radii less than 20 AU due to truncation in dynamical encounters. This is consistent with observations of the Orion Trapezium Cluster and implies that most stars and brown dwarfs do not form large planetary systems.

Accepted by MNRAS

http://www.astro.ex.ac.uk/people/mbate

## Spectroscopic diagnostics of UV power and accretion in T Tauri stars

**D. H. Brooks[1] and V. M. Costa[2,3]**

[1] Kwasan and Hida Observatories, Kyoto University, Yamashina-ku, Kyoto-shi, 607-8471, Japan
[2] Centro de Astrofisica da Universidade do Porto, Rua das Estrelas, Porto 4150, Portugal
[3] Departamento de Matemática, Instituto Superior de Engenharia do Porto, Portugal

E-mail contact: dbrooks@kwasan.kyoto-u.ac.jp

It is known that in the upper atmospheres of the Sun and some late type stars there is a systematic relationship between the optically thin total radiated power and the power emitted by single spectral lines. Using recently derived emission measure distributions from IUE spectra for BP Tau, CV Cha, RY Tau, RU Lupi and GW Ori, we demonstrate that this is also true for classical T Tauri stars (CTTS). As in the solar case it is found that the C IV resonance doublet at 1548Å is also the most accurate indicator of the total radiated power from the atmospheres of CTTS. Since the total radiated power density in CTTS exceeds that of the Sun by over 3 orders of magnitude we derive new analytic expressions that can be used to estimate the values for these stars. We also discuss the implications of these results with regard to the influence or absence of accretion in this sample of stars and suggest that the method can be used to infer properties of the geometrical structure of the emission regions.

As a demonstration case we also use archived HST-GHRS data to estimate the total radiative losses in the UV emitting region of BP Tau. We find values of $4.57 \times 10^9$ ergs cm$^{-2}$ s$^{-1}$ and $5.11 \times 10^{32}$ ergs s$^{-1}$ dependent on the geometry of the emission region. These results are several orders of magnitude larger than would be expected if the UV emission came primarily from an atmosphere covered in solar-like active regions and are closer to values associated with solar flares. They lead to luminosity estimates of $0.07 L_\odot$ and $0.13 L_\odot$, respectively, which are in broad agreement with results obtained from theoretical accretion shock models. Taken together they suggest that accretion may well be the dominant contributor to the UV emission in BP Tau.

Accepted by MNRAS

## Discovery of calcite in the solar type protostar NGC1333-IRAS4

**C. Ceccarelli[1], E. Caux[3], A.G.G.M. Tielens[4], F. Kemper[5], L.B.F.M. Waters[6], T. Phillips[7]**

[1] Observatoire de Bordeaux, BP 89, 33270 Floirac - France
[2] Laboratoire d'Astrophysique de l'Observatoire de Grenoble - France
[3] CESR CNRS-UPS, BP 4346, 31028 - Toulouse cedex 04 - France
[4] SRON, P.O. Box 800, NL-9700 AV Groningen - The Netherlands
[5] Astronomical Institute Anton Pannekoek, University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam - The

Netherlands
[6] Instituut voor Sterrenkunde, KU Leuven, Celestijnenlaan 200B, 3001 Heverlee - Belgium
[7] California Institute of Technology, Downs Laboratory of Physics 320-47, Pasadena, CA 91125 - USA

E-mail contact: ceccarel@observ.u-bordeaux.fr

We present observations, obtained with ISO-LWS, of the continuum between 50-200 $\mu$m of the solar type protostar IRAS4, in the NGC1333 complex. The continuum presents an excess, around 95 $\mu$m, that we demonstrate must be a dust feature. We compared the 95 $\mu$m excess with the calcite feature at 92 $\mu$m and find that it fits the observations reasonably well. There may be a further contribution from hydrous silicates at $\sim$100 $\mu$m, but this seems a less robust result. The detected calcite mass is $\sim 8 \times 10^{-5}$ $M_\odot$ and represents about 1% of the warm ($\sim$ 23 K) dust mass surrounding IRAS4. This is only the second observation indicating the presence of carbonates outside the solar system, and the first revealing calcite in a young protostar. It is remarkable and intriguing that in all the objects where calcite has been detected so far, namely meteorites, planetary nebulae and IRAS4, it represents from 0.3 to 1% of the dust mass. This new detection of calcite strengthens the claim by Kemper et al. (2002a) that calcite formation does not necessarely requires liquid water. We suggest that calcite forms at the surface of the grains, where water ice layers may locally have an enhanced mobility caused by heating due to hard X-rays emitted by the central object.

Accepted by A&A Letters

*http://www.observ.u-bordeaux.fr/*

## Near-IR echelle spectroscopy of Class I protostars: mapping Forbidden Emission-Line (FEL) regions in [FeII]

**Christopher J. Davis[1], Emma Whelan[2], Thomas P. Ray[2] & Antonio Chrysostomou[3]**

[1]Joint Astronomy Centre, 660 N. A'ohōkū Place, University Park, Hilo, Hawaii 96720, U.S.A.
[2]Dublin Institute for Advanced Studies, School of Cosmic Physics, 5 Merrion Square, Dublin 2, Ireland.
[3]Department of Physical Sciences, University of Hertfordshire, Hatfield, Herts AL10 9AB, U.K.

E-mail contact: c.davis@jach.hawaii.edu

Near-IR echelle spectra in [FeII] 1.644$\mu$m emission trace Forbidden Emission Line (FEL) regions towards seven Class I HH energy sources (SVS 13, B5-IRS1, IRAS 04239+2436, L1551-IRS5, HH 34-IRS, HH 72-IRS and HH 379-IRS) and three classical T Tauri stars (AS 353A, DG Tau and RW Aur). The parameters of these FEL regions are compared to the characteristics of the Molecular Hydrogen Emission Line (MHEL) regions recently discovered towards the same outflow sources (Davis et al. 2001 – Paper I). The [FeII] and $H_2$ lines both trace emission from the base of a large-scale collimated outflow, although they clearly trace different flow components. We find that the [FeII] is associated with higher-velocity gas than the $H_2$, and that the [FeII] emission peaks further away from the embedded source in each system. This is probably because the [FeII] is more closely associated with HH-type shocks in the inner, on-axis jet regions, while the $H_2$ may be excited along the boundary between the jet and the near-stationary, dense ambient medium that envelopes the protostar. Indeed, there is spatial and kinematic evidence that [FeII] and the more typically-used optical emission lines, the red [SII] doublet, do trace almost the same shock-excited regions in HH jets and FEL regions alike.

Accepted by A&A

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

## A New Algorithm for Radiative Feedback and its Application to the Formation of Massive Stars

**R.G. Edgar[1] & C.J. Clarke[1]**

[1] Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, Great Britain

E-mail contact: rge21@ast.cam.ac.uk

We have developed a simplified method of treating the radiative acceleration of dusty flows. This method retains the sharp impulse at the dust destruction radius that is a feature of frequency dependent radiative transfer, whilst placing minimal demands on computing resources. As such, it is suitable for inclusion in hydrodynamic codes. We

have applied this method to the formation of massive stars in spherical geometry, and find that the fraction of a cloud which can accrete on to the central star is a strong function of the Jeans' Number and density profile of the cloud. Massive star formation is favoured by cold homogeneous conditions, as might result in regions where gas is swept up by some external triggering agent. We find (in contrast to previous authors) that massive star formation does not require a depleted dust mixture, although the use of dust at typical interstellar abundances does reduce the final stellar mass compared to cores formed from a depleted mixture.

Accepted by Monthly Notices

Preprint available at: http://www.arXiv.org/abs/astro-ph/0210340

## Constraints on Star Formation from the Close Packing of Protostars in Clusters

**Bruce Elmegreen[1] and Mohsen Shadmehri[2]**

[1] IBM Research Division, T.J. Watson Research Center, P.O. Box 218, Yorktown Heights, NY 10598, USA
[2] Department of Physics, School of Science, Ferdowsi University, Mashhad, Iran

E-mail contact: bge@watson.ibm.com

The mm-wave continuum sources (MCS) in Ophiuchus have mutual collision rates less than their collapse rates by a factor of 10 to 100, suggesting most will form stars without further interactions. However, the ratio of these rates would have exceeded unity in the past if they were only 2.5 times larger than they are now. Such a high previous ratio suggests three possible scenarios: (1) the MCS contracted from lower densities and acquired their present masses through collisional agglomeration, (2) they contracted independently from lower densities elsewhere and moved to the cluster core recently, or (3) they grew from smaller sizes at a constant high density. The third of these is most likely, implying that the MCS formed in the shocked regions of a supersonically turbulent fluid. The first scenario gives the wrong mass function and the second does not give the observed hierarchical clustering. The ratio of rates also exceeds unity today if the MCS have envelopes with smooth profiles that end in pressure balance with the ambient cloud cores; this suggests again that turbulent flows define their outer layers. Proximity constraints like this are even more important in massive clusters, including globular clusters, in which massive stars with the same or greater space density are more strongly interacting than the Ophiuchus MCS. As a result, the density contrast for MCS must be larger in massive clusters than it is in Ophiuchus or else significant coalescence will occur in the protostellar phase, possible forming massive black holes. A proportionality to the second power of the Mach number allows the MCS cores to collapse independently. These results suggest that stars in dense clusters generally form on a dynamical time by the continuous collection and rapid collapse of turbulence-shocked gas. Implications of proximity constraints on the initial stellar mass function are also discussed. Warm cloud cores can produce a top-heavy IMF because of a simultaneous increase in the thermal Jeans mass and the collisional destruction rate of low mass MCS.

Accepted by MNRAS

astro-ph/0210246

## X-rays in the Orion Nebula Cluster: Constraints on the origins of magnetic activity in pre-main sequence stars

**Eric D. Feigelson[1], James A. Gaffney III[1], Gordon Garmire[1], Lynne A. Hillenbrand[2] and Leisa Townsley[1]**

[1] Department of Astronomy & Astrophysics, 525 Davey Laboratory, Pennsylvania State University, University Park PA 16802, USA
[2] Department of Astronomy, MS 105-24, California Institute of Technology, Pasadena CA 91125, USA

E-mail contact: edf@astro.psu.edu

A recent observation of the Orion Nebula Cluster with the ACIS instrument on board the *Chandra* X-ray Observatory detected 1075 sources (Feigelson et al. 2002), 525 of which are pre-main sequence (PMS) stars with measured bulk properties (bolometric luminosities, masses, ages and disk indicators). Nearly half of these stars have photometrically measured rotational periods. This provides a uniquely large and well-defined sample to study the dependence of magnetic activity on bulk properties for stars descending the Hayashi tracks.

The following results are obtained: (1) X-ray luminosities $L_t$ in the $0.5 - 8$ keV band are strongly correlated with bolometric luminosity with average ratio $\log L_t/L_{bol} = -3.8$ for stars with masses $0.7 < M < 2$ $M_\odot$, an order of magnitude below the main sequence saturation level; (2) the X-ray emission drops rapidly below this level in some or all stars with $2 < M < 3$ $M_\odot$; (3) the presence or absence of infrared circumstellar disks has no apparent relation to X-ray levels; and (4) X-ray luminosities exhibit a slight rise as rotational periods increase from 0.4 to 20 days. This last finding stands in dramatic contrast to the strong anticorrelation between X-rays and period seen in main sequence stars.

The absence of a strong X-ray/rotation relationship in PMS stars, and particularly the high X-ray values seen in some very slowly rotating stars, is a clear indication that the mechanisms of magnetic field generation differ from those operating in main sequence stars. The most promising possibility is a turbulent dynamo distributed throughout the deep convection zone, but other models such as $\alpha - \Omega$ dynamo with 'supersaturation' or relic core fields are not immediately excluded. The drop in magnetic activity in intermediate-mass stars may reflect the presence of a significant radiative core. The evidence does not support X-ray production in large-scale star-disk magnetic fields.

Accepted by Astrophys. J.

Preprints available at http://arXiv.org/abs/astro-ph/0211049

## Formation of protostellar jets – effects of magnetic diffusion

**Christian Fendt[1,2] and Miljenko Cemeljić[2]**

[1] Universität Potsdam, Institut für Physik, Am Neuen Palais 10, D-14469 Potsdam, Germany

[2] Astrophysikalisches Institut Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany

E-mail contact: cfendt@aip.de

Protostellar jets most probably originate in turbulent accretion disks surrounding young stellar objects. We investigate the evolution of a disk wind into a collimated jet under the influence of magnetic diffusivity, assuming that the turbulent pattern in the disk will also enter the disk corona and the jet. Using the ZEUS-3D code in the axisymmetry option we solve the time-dependent resistive MHD equations for a model setup of a central star surrounded by an accretion disk. The disk is taken as a time-independent boundary condition for the mass flow rate and the magnetic flux distribution.

We derive analytical estimates for the magnitude of magnetic diffusion in a protostellar jet connecting our results to earlier work in the limit of ideal MHD. We find that the diffusive jets propagate slower into the ambient medium, most probably due to the lower mass flow rate in the axial direction. Close to the star we find that a quasi stationary state evolves after several hundred (weak diffusion) or thousand (strong diffusion) disk rotations.

Magnetic diffusivity affects the protostellar jet structure as follows. The jet poloidal magnetic field becomes decollimated. The jet velocity increases with increasing diffusivity, while the degree of collimation for the hydrodynamic flow remains more or less the same. We suggest that the mass flux is a proper tracer for the degree of jet collimation and find indications of a critical value for the magnetic diffusivity above which the jet collimation is only weak. We finally develop a self-consistent picture in which all these effects can be explained in the framework of the Lorentz force.

Accepted by Astron. & Astrophys.

Preprint: astro-ph/0210082

## Observational clues for a role of circumstellar accretion in PMS X-ray activity

**E. Flaccomio, G. Micela, and S. Sciortino**

INAF - Osservatorio Astronomico di Palermo G.S. Vaiana, Palazzo dei Normanni, I-90134 Palermo, Italy

E-mail contact: ettoref@oapa.astropa.unipa.it

We revisit the published analyses of ROSAT X-ray observations of the star forming regions NGC 2264 and Chamaeleon I ($\sim 3$ and $\sim 5$ Myr old respectively) in the light of newly published optical data. At odds with previous results on Chamaeleon I members, we find that low mass stars in both regions have near-saturated emission levels. Similarly to what previously found in the Orion Nebula Cluster, Weak Line T-Tauri Stars in NGC 2264 and in the Chamaeleon I cloud have higher X-ray activity levels respect to Classical T Tauri Stars, arguing in favor of a role of the disk and/or

accretion in determining X-ray emission.

Accepted by A&A

*For preprints via WWW*: http://www.astropa.unipa.it/Library/preprint.html

## A detailed study of G35.2–0.7N: collimated outflows in a cluster of high-mass young stellar objects

**A.G. Gibb[1,2], M.G. Hoare[2], L.T. Little[3] and M.C.H. Wright[4]**

[1] Department of Astronomy, University of Maryland, College Park, MD 20742, USA

[2] Department of Physics and Astronomy, University of Leeds, Leeds, West Yorkshire, LS2 9JT, UK

[3] Electronic Engineering Laboratory, University of Kent at Canterbury, Kent, CT2 7NT, UK

[4] Radio Astronomy Laboratory, Department of Astronomy, University of California, 601 Campbell Hall, Berkeley, CA 94720, USA

E-mail contact: agg@astro.umd.edu

We present a series of JCMT, BIMA and VLA observations of the massive star-forming region associated with G35.2–0.7N. These new observations shed considerable light on the nature of the outflows in this region. The combination of our CO, SiO and radio data suggest that there are perhaps as many as four outflows emanating from the core containing G35.2–0.7N. CO $J$=3→2 maps show that the outflow has a curved appearance consistent with precession of a central driving source. However, the geometric centre of the flow is found to be not coincident with the radio jet source G35.2N but is instead closer to a peak in SiO, $H^{13}CO^+$ and dust continuum found in the BIMA data. An elongated finger of CO emission is detected to the north of centre which points back towards the radio jet centred on G35.2N, further ruling it out as the driving source of the larger-scale CO flow. BIMA observations of the 3.5-mm continuum (which is dominated by dust), $H^{13}CN$ and $H^{13}CO^+$ emission trace a dense, elongated, rotating envelope with properties in good agreement with values derived from previous ammonia observations. The peak of the dust continuum and the $H^{13}CO^+$ peak a few arcsec to the south of G35.2N. SiO $J$=2→1 data delineate a well-collimated feature parallel with the axis of the CO outflow, but offset to the north by ∼10 arcsec. $H^{13}CO^+$ emission is detected at the possible origin of this flow but no radio source is observed. VLA A-configuration observations at 6- and 3.5 cm resolve the radio jet into at least six discrete components, with positions consistent with previous observations. The central driving source, G35.2N, is only detected at 3.5 cm. At least two other sources are detected, one of which lies within the flattened core and may be associated with another flow inferred from recent $L'$-band observations. No radio source is detected at the geometric centre of the CO outflow.

Accepted by MNRAS

http://arxiv.org/abs/astro-ph/0211059

## Comments on Inferences of Star Formation Histories and Birthlines

**Lee Hartmann[1]**

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

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

Palla & Stahler have recently argued that star formation in Taurus and other nearby molecular clouds extends over a period of at least 10 Myr, implying quasi-static cloud evolution and star formation. Their conclusions contradict other recent results indicating that molecular clouds are transient objects and star formation proceeds rapidly. The Palla & Stahler picture implies that most molecular clouds should have extremely low rates of star formation, and that in such inactive stages the stellar initial mass function should be strongly skewed toward producing stars with masses $\geq 1 M_\odot$; neither prediction is supported by observations. I show that the Palla & Stahler conclusions for Taurus depend almost entirely on a small number of stars with masses $\geq 1 M_\odot$; the lower-mass stars show no evidence for such an extended period of star formation. I further show that most of the stars apparently older than 10 Myr in the direction of Taurus are probably foreground non-members. I also present birthline calculations which support the idea that the ages of the stars with masses $\geq 1 M_\odot$ have been systematically overestimated because "birthline" age corrections have been underestimated; such birthlines would eliminate the need to postulate skewed initial mass functions. The simplest and most robust explanation of current observations characterizing the vast majority of young stars in molecular clouds is

that cloud and star formation is rapid and dynamic.

Accepted by Ap. J.

http://cfa-www.harvard.edu/cfa/youngstars/

## Protoplanetary Disk Mass Distribution in Young Binaries

**Eric L. N. Jensen[1] and Rachel L. Akeson[2]**

[1] Swarthmore College Department of Physics and Astronomy, Swarthmore, PA 19081, USA
[2] Interferometry Science Center, Caltech, MS 100-22, 1201 E. California Blvd., Pasadena, CA 91125, USA

E-mail contact: ejensen1@swarthmore.edu

We present millimeter-wave continuum images of four wide (separations 210–800 AU) young stellar binary systems in the Taurus-Auriga star-forming region. For all four sources, the resolution of our observations is sufficient to determine the mm emission from each of the components. In all four systems, the primary star's disk has stronger millimeter emission than the secondary and in three of the four, the secondary is undetected; this is consistent with predictions of recent models of binary formation by fragmentation. The primaries' circumstellar disk masses inferred from these observations are comparable to those found for young single stars, confirming that the presence of a wide binary companion does not prevent the formation of a protoplanetary disk. Some of the secondaries show signatures of accretion (H$\alpha$ emission and $K-L$ excesses), yet their mm fluxes suggest that very little disk mass is present.

Accepted by Ap. J. (to appear Feb. 2003)

Preprint available at `http://astro.swarthmore.edu/~jensen/publications.html` .

## Direct Detection of the Companion of $\chi^1$ Orionis

**Brigitte Koenig[1], Klaus Furhmann[1] Ralph Neuhäuser[1], David Charbonneau[2] and Ray Jayawardhana[3]**

[1] Max-Planck-Institut für extraterrestrische Physik, Giessenbachstrasse, 85748 Garching, Germany
[2] Astronomy, California Institute of Technology, Pasadena, CA 91125, U.S.A.
[3] Department of Astronomy, University of Michigan, Ann Arbor, MI 48104, U.S.A.

E-mail contact: bkoenig@mpe.mpg.de

We present an H-band image of the companion of $\chi^1$ Orionis taken with the Keck adaptive optic system and NIRC2 camera equipped with a 300mas-diameter coronographic mask. The direct detection of this companion star enables us to calculate dynamical masses using only Kepler's laws $M_A = 1.01 \pm 0.13\ M_{Sun}$, $M_B = 0.15 \pm 0.02\ M_{Sun}$, and to study stellar evolutionary models at a wide spread of masses. The application of Baraffe et al. (1998) pre-main-sequence models implies an age of 70-130 Myrs. This is in conflict to the age of the primary, a confirmed member of the Ursa Major Cluster with a canonical age of 300 Myrs. As a consequence, either the models at low masses underestimate the age or the Ursa Major Cluster is considerably younger than assumed.

Accepted by Astronomy & Astrophysics

Available at http://arxiv.org/abs/astro-ph/0209404

## Probing the structure of a birthplace of intermediate-mass stars: Ammonia cores in Lynds 1340

**M. Kun[1], J. G. A. Wouterloot[2] and L. V. Tóth[3,4]**

[1] Konkoly Observatory, H-1525 Budapest, P.O.Box 67, Hungary
[2] Joint Astronomy Centre, 660 N. A'ohoku Place, University Park, 96720 Hilo, Hawaii, USA
[3] Department of Astronomy, Loránd Eötvös University, H-1117 Budapest, Pázmány Péter sétány 1, Hungary
[4] Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany

E-mail contact: kun@konkoly.hu

Lynds 1340, a molecular cloud forming intermediate-mass stars, has been mapped in the $NH_3$(1,1) and (2,2) transitions with the Effelsberg 100-m telescope. We observed the whole area of the cloud where $C^{18}O$ emission was detected earlier, at a 40 arcsec grid, with additional positions towards the $C^{18}O$ peaks and optically invisible IRAS point sources. Our observations covered an area of 170 arcmin$^2$, corresponding to about 5.15 pc$^2$ at a distance of 600 pc, and revealed 10 ammonia cores. The cores, occupying some 7 % of the mapped area, probably represent the highest density regions of L 1340. Their total mass is $\sim$80 $M_\odot$, about 6 % of the mass traced by $C^{18}O$. Six cores are associated with optically invisible IRAS point sources. Their average nonthermal line width is 0.78 km s$^{-1}$, while the same quantity for the four starless cores is 0.28 km s$^{-1}$. We suggest that the narrow-line cores are destined to form low-mass stars, whereas small groups of intermediate-mass stars are being formed in the turbulent cores. The features traced by $NH_3$, $^{13}CO$, $C^{18}O$ and HI obey the line width–size relation $\Delta v_{\rm NT} \propto R_{1/2}^{0.41}$. Comparison of sizes, densities and nonthermal line widths of ammonia cores with those of $C^{18}O$ and $^{13}CO$ structures supports the scenario in which core formation has been induced by turbulent fragmentation. The typical physical properties of the $NH_3$ cores of L 1340, $\langle R_{1/2}\rangle$=0.08 pc, $\langle T_{\rm kin}\rangle$=13.8 K, $\langle \Delta v_{\rm total}\rangle$=0.64 km s$^{-1}$, and $\langle M\rangle$=9 $M_\odot$ are close to those of the high-mass star forming Perseus and Orion B clouds.

Accepted by A&A

Preprints: astro-ph/0211180

## A Survey for Circumstellar Disks Around Young Substellar Objects

**Michael C. Liu[1], Joan Najita[2] and Alan T. Tokunaga[1]**

[1] Institute for Astronomy, University of Hawai'i, 2680 Woodlawn Drive, Honolulu, HI 96822, USA
[2] National Optical Astronomy Observatory, 950 North Cherry Avenue, Tucson, AZ 85719, USA

E-mail contact: mliu@ifa.hawaii.edu

We have completed the first systematic survey for disks around spectroscopically identified young brown dwarfs and very low mass stars. For a sample of 38 very cool objects in IC 348 and Taurus, we have obtained $L'$-band (3.8 $\mu$m) imaging with sufficient sensitivity to detect objects with and without disks. The sample should be free of selection biases for our purposes. Our targets span spectral types from M6 to M9.5, corresponding to masses of $\sim$15 to 100 $M_{Jup}$ and ages of $\lesssim$5 Myr based on current models. None appear to be binaries at 0.″4 resolution (55–120 AU). Using the objects' measured spectral types and extinctions, we find that most of our sample (77% $\pm$ 15%) possess intrinsic IR excesses, indicative of circum(sub)stellar disks. Because the excesses are modest, conventional analyses using only IR colors would have missed most of the sources with excesses. Such analyses inevitably underestimate the disk fraction and will be less reliable for young brown dwarfs than for T Tauri stars. The observed IR excesses are correlated with H$\alpha$ emission, consistent with a common accretion disk origin. In the same star-forming regions, we find that disks around brown dwarfs and T Tauri stars are contemporaneous; assuming coevality, this demonstrates that the inner regions of substellar disks are at least as long-lived as stellar disks and evolve slowly for the first $\sim$3 Myr. The disk frequency appears to be independent of mass. However, some objects in our sample, including the very coolest (lowest mass) ones, lack IR excesses and may be diskless. The observed excesses can be explained by disk reprocessing of starlight alone; the implied accretion rates are at least an order of magnitude below typical values for classical T Tauri stars. The observed distribution of IR excesses suggests inner disk holes with radii of $\gtrsim 2R_\star$, consistent with the idea that such holes arise from disk-magnetosphere interactions. Altogether, the frequency and properties of young circumstellar disks appear to be similar from the stellar regime down to the substellar and planetary-mass regime. This provides prima facie evidence of a common origin for most stars and brown dwarfs.

Accepted by Astrophysical Journal.

http://xxx.lanl.gov/abs/astro-ph/0210523

http://www.ifa.hawaii.edu/m̃liu/Research/bd_disks/bd_disks.html

## Orbital proper motions in the proto-binary system L1527/IRAS 04368+2557?

**Laurent Loinard[1], Luis F. Rodríguez[1], Paola D'Alessio[1], D.J. Wilner[2] and Paul T.P. Ho[2]**

[1] Instituto de Astronomía, Universidad Nacional Autónoma de México, Apartado Postal 72–3 (Xangari), 58089 Morelia, Michoacán, México
[2] Harvard Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: l.loinard@astrosmo.unam.mx

Using high angular resolution 7 mm VLA observations, we show that the low-mass protostellar object IRAS 04368+2557 in L1527 is comprised of two radio sources separated in projection by 25 AU. One of the two components is extended in the direction perpendicular to the outflow powered by IRAS 04368+2557, and is, most likely, a compact accretion disk (R $\sim$ 20 AU), similar to those found in L1551 IRS5 by Rodríguez et al. (1998). As in L1551 IRS5, the disk found here is small compared to those around T–Tauri stars. Tidal interactions with nearby companions provide a natural way of truncating disks, and we argue that the two millimeter wavelength sources in L1527 trace a compact binary system, where the disk surrounding one of the components has been truncated by the tidal influence of the other. A comparison between observations obtained in 1996 and 2002 reveals large proper motions, which can only partly be attributed to the overall large-scale motion of the region in which IRAS 04368+2557 is located. The remaining "residual" proper motions might trace the orbital motion of the binary, and would suggest a total mass for the system larger than 0.2 $M_\odot$, and likely of the order of 0.5 to 2 $M_\odot$. This mass (only a small fraction of which is in the disk) is of the same order as that of the extended surrounding envelope of gas and dust traced by far-infrared and sub-millimeter observations ($M_{env} \sim 0.5$ $M_\odot$), implying that the stars that will eventually form out of IRAS 04368+2557 would have already acquired a significant fraction of their final masses. It is worth noting that multi–epoch VLA studies of nearby protobinary systems similar to that presented here, could provide direct mass estimates in most nearby star-forming sites. Combined with submillimeter observations of the surrounding envelopes, this would provide a more reliable measure of the evolutionary status of binary protostars

Accepted by the Astrophysical Journal Letters

Preprints available at http://www.astrosmo.unam.mx/ l.loinard/publi.html

## Viscous diffusion and photoevaporation of stellar disks

**Isamu Matsuyama[1], Doug Johnstone[2] and Lee Hartmann[3]**

[1] Department of Astronomy and Astrophysics,University of Toronto, Toronto, ON M5S 3H8, Canada
[2] National Research Council Canada, Herzberg Institute of Astrophysics, 5071 West Saanich Road, Victoria, BC V9E 2E7, Canada
[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: isamu@astro.utoronto.ca, doug.johnstone@nrc.ca

The evolution of a stellar disk under the influence of viscous evolution, photoevaporation from the central source, and photoevaporation by external stars is studied. We take the typical parameters of TTSs and the Trapezium Cluster conditions. The photoionizing flux from the central source is assumed to arise both from the quiescent star and accretion shocks at the base of stellar magnetospheric columns, along which material from the disk accretes. The accretion flux is calculated self-consistently from the accretion mass loss rate. We find that the disk cannot be entirely removed using only viscous evolution and photoionization from the disk-star accretion shock. However, when FUV photoevaporation by external massive stars is included the disk is removed in $10^6 - 10^7$yr; and when EUV photoevaporation by external massive stars is included the disk is removed in $10^5 - 10^6$yr.

An intriguing feature of photoevaporation by the central star is the formation of a gap in the disk at late stages of the disk evolution. As the gap starts forming, viscous spreading and photoevaporation work in resonance. When viscous accretion and photoevaporation by the central star and external massive stars are considered, the disk shrinks and is truncated at the gravitational radius, where it is quickly removed by the combination of viscous accretion, viscous spreading, photoevaporation from the central source, and photoevaporation by the external stars. There is no gap formation for disks nearby external massive stars because the outer annuli are quickly removed by the dominant EUV flux. On the other hand, at larger, more typical distances ($d \gg 0.03$pc) from the external stars the flux is FUV dominated. As a consequence, the disk is efficiently evaporated at two different locations; forming a gap during the last stages of the disk evolution

Accepted by Astrophysical Journal

astro-ph/0209498

## Discovery of a Near-Infrared Jet-Like Feature in the Z Canis Majoris System

**R. Millan-Gabet[1,2] and J. D. Monnier[1,3]**

[1] Harvard-Smithsonian Center for Astrophysics, Cambridge MA 02138, USA
[2] now at: Caltech/Interferometry Science Center, Pasadena, CA 91125, USA
[3] now at: University of Michigan, Ann Arbor, MI 48901, USA
E-mail contact: rmillan@cfa.harvard.edu,jmonnier@cfa.harvard.edu

We present near-infrared high resolution observations of the young binary system Z Canis Majoris using the adaptive optics system at the Keck-II telescope. Both components are unresolved at 1.25 $\mu$m and 1.65 $\mu$m, although high dynamic range images reveal a previously unknown jet-like feature in the circumstellar environment. We argue that this feature probably arises from light scattered off the walls of a jet-blown cavity, and proper motion studies of this feature can probe the dynamics of the bipolar outflow. Potentially, the morphology of the dust-laden cavity walls offers a new probe of the momentum profile and collimation of bipolar winds from young stellar objects. We also derive high precision binary parameters, which when combined with historical data have allowed the first detection of orbital motion. Lastly, our observations confirm the high degree of flux variability in the system; the North-West binary component is dominant at H-band, in contrast to all previous observations.

Accepted by Astrophysical Journal Letters

Preprint available at: http://xxx.lanl.gov/pdf/astro-ph/0210376

## A high spectral resolution VLBI study of the 12 GHz methanol masers in W3(OH) – Their sub-milliarcsecond structure and clues on saturation

**L. Moscadelli[1], K.M. Menten[2], C.M. Walmsley3, and M.J. Reid[4]**

[1] Osservatorio Astronomico di Cagliari, Loc. Poggio dei Pini, Str. 54, 09012 Capoterra (CA), Italy
[2] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
[3] Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy
[4] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
E-mail contact: mosca@ca.astro.it

This paper reports on the results of high velocity resolution (0.02 km $s^{-1}$) VLBA observations of the 12 GHz methanol masers towards the UC HII region W3(OH). About 50 maser features are detected, and their emission is resolved both in velocity and in space (with an angular resolution of $\approx 1$ mas). The maser feature spectra are very well reproduced by single Gaussian profiles, and a narrow distribution for the FWHM linewidths is found, from 0.14 km $s^{-1}$ to 0.32 km $s^{-1}$. The measured brightness temperatures distribute over the range $10^{10} - 2 \times 10^{12}$ K.

By performing elliptical Gaussian fits, the spot parameters (peak position, intensity and FWHM sizes) in the high velocity resolution maps were derived. The highest brightness temperatures occur in correspondence with the smallest spots, with FWHM size $\leq 4$ AU. For all the maser features, it is found that the channel peak positions vary smoothly with the velocity, delineating straight or arc-like distributions projected onto the sky. In most cases, the channel (line-of-sight) velocities vary linearly with the peak positional shifts, with measured gradients in the range $0.05 - 0.65$ km $s^{-1}$ $mas^{-1}$ ($0.02 - 0.30$ km $s^{-1}$ $AU^{-1}$).

Most of the maser spot spectra have very small deviations from a Gaussian profile, $\leq 2\ 10^{-3}$, and a trend for decreasing deviations with increasing intensities is noted. In most cases, the kurtosis of the spectral profiles is positive, with the most accurate values concentrated in the range $0.1 - 0.5$. Comparison of these results with recent calculations of the deviations from a Gaussian profile which occur across the line profile of a linear maser (as a result of the amplification process), suggests that the 12 GHz $CH_3OH$ masers are below the threshold, $I_0$, at which line rebroadening occurs. However, the model predicts deviations from a Gaussian profile significantly smaller than the observed values, and this discrepancy needs to be investigated. In particular, the calculations of the deviations from a Gaussian profile should take into account the effects of a velocity gradient through the maser features (evidenced by our observations), which will influence the spectral profile. The maximum output given by the pump rate of saturated masers may account for the observational result that the highest intensities are found in correspondence with the smallest sky-projected spot areas.

Accepted by Astrophysical Journal

ftp://mailserver.ca.astro.it/outgoing/mosca/w3oh_highres.ps.gz

## A Spectrophotometric Method to Determine the Inclination of Class I Objects

**Takeshi Nakazato**[1], **Taishi Nakamoto**[1] **and Masayuki Umemura**[1]

[1] Center for Computational Physics, University of Tsukuba, Tsukuba 305-8577, Japan

E-mail contact: nakazato@rccp.tsukuba.ac.jp

A new method which enables us to estimate the inclination of Class I young stellar objects is proposed. Since Class I objects are not spherically symmetric, it is likely that the observed feature is sensitive to the inclination of the system. Thus, we construct a protostar model by carefully treating two-dimensional (2D) radiative transfer and radiative equilibrium. We show from the present 2D numerical simulations that the emergent luminosity $L_{\rm SED}$, which is the frequency integration of spectral energy distribution (SED), depends strongly on the inclination of the system $i$, whereas the peak flux is insensitive to $i$. Based on this result, we introduce a novel indicator $f_{\rm L}$, which is the ratio of $L_{\rm SED}$ to the peak flux, as a good measure for the inclination. By using $f_{\rm L}$, we can determine the inclination regardless of the other physical parameters. The inclination would be determined by $f_{\rm L}$ within the accuracy of $\pm 5°$, if the opening angle of bipolar outflows is specified by any other procedure. Since this spectrophotometric method is easier than a geometrical method or a full SED fitting method, this method could be a powerful tool to investigate the feature of protostars statistically with observational data which will be provided by future missions, such as *SIRTF*, *ASTRO-F*, and *ALMA*.

Accepted by Astrophysical Journal

astro-ph/0210252

## Observations of high-J SiO emission along the HH211 outflow

**Brunella Nisini**[1], **Claudio Codella**[2], **Teresa Giannini**[1] **and John S. Richer**[3]

[1] INAF-Osservatorio Astronomico di Roma, I-00040 Monteporzio Catone, Italy
[2] Istituto di Radioastronomia, CNR, Sezione di Firenze, Largo E. Fermi 5, I-50125 Firenze, Italy
[3] Department of Physics, University of Cambridge, Cavendish Laboratory, Madingley Road, CB3 0HE, UK

E-mail contact: bruni@mporzio.astro.it

Spectra of the pure rotational SiO $J$=11-10 and $J$=8-7 lines, at 477.5 GHz and 347.3 GHz respectively, have been obtained along the HH211 protostellar jet. Bright emission has been observed localized inside about 15″ of projected distance from the central source, where a compact and collimated SiO jet was previously discovered by means of SiO $J$=1-0 interferometric observations (Chandler & Richer 2001). The detection of the high-$J$ lines testifies for the extreme conditions of density and temperature of the SiO emission. Values of $T > 250$ K and $n_{H2}$ ∼2–5×$10^6$ cm$^{-3}$ are inferred from the observed line ratios, while a SiO abundance in the range ∼$10^{-7}$–$10^{-6}$ has been estimated through a comparison with the CO rotational lines at $J > 14$ observed by the ISO Long Wavelength Spectrometer. Both the estimated physical conditions and abundance are in agreement with a picture in which the observed SiO emission directly arises at the front of a C-type shock with $v_s < 35$ km s$^{-1}$, where all the silicon released from the grains by sputtering and/or grain-grain collisions is converted into gas-phase SiO.

Accepted by A&A Letters

Preprints available at `http://www.mporzio.astro.it/~bruni/publ.html`

## High Proper Motion Features in the Central Orion Nebula

**C. R. O'Dell**[1], **Takao Doi**[2]

[1] Department of Physics and Astronomy, Vanderbilt University, Box 1807-B, Nashville, TN 37235, USA
[2] NASA Johnson Space Center, 2101 NASA Road 1, Houston, TX 77058-3696, USA

E-mail contact: cr.odell@vanderbilt.edu

The brightest portion of the Orion Nebula has been reimaged with the HST in H$\alpha$, [N II], , and [O III]. Comparison with earlier WFPC2 images going back as much as 8 yrs has allowed determination of tangential velocities (proper motions) down to about 10 km s$^{-1}$ for a variety of sources. Multiple outflow systems are found associated with individual proplyds in the ionized portion of the nebula (HH 518, HH 624, possibly HH 507).

The Orion-S complex of radio and infrared sources is the source of multiple outflows. A new outflow system (HH 625) has been identified as coming from the blue-shifted portion of the imbedded high velocity CO flow coming from the Orion-S region, this object having CO, $H_2$, and low ionization optical components. The low velocity CO outflow originating from or near FIR 4 is the likely source of HH 530.

A new imbedded source is inferred from this optical data to lie in Orion-S. This Optical Outflow Source (OOS) clearly feeds the systems HH 269 and HH 529, which lie along a straight line. There is evidence that this is also the sour ce for HH 528, HH 202, and HH 203+HH 204, all of which are blue-shifted (except possibly HH 528 whose radial velocity is unknown). There is no strong radio, infrared, or x-ray source within the positional ellipse of the OOS.

Accepted by Astron. J.

Postscript files can be obtained from the anonymous ftp server orion.phy.vanderbilt.edu within the directory pub/outgoing/OrionMotions.

## Near and Mid-infrared images of the massive star forming complex G9.62+0.19

**P. Persi[1], M. Tapia[2], M. Roth[3], A.R. Marenzi[1], L. Testi[4] and L.Vanzi[5]**

[1] Istituto Astrofisica Spaziale e Fisica Cosmica, CNR, Via del Fosso del Cavaliere, I-00133, Roma, Italy
[2] Instituto de Astronomía, UNAM, Apartado Postal 877, Ensenada, Baja California, CP 22833, Mexico
[3] Las Campanas Observatory, Carnegie Inst. of Washington, Casilla 601, La Serena, Chile
[4] Osservatorio Astrofisico di Arcetri, Largo E.Fermi 5, 50125 Firenze, Italy
[5] European Southern Observatory, Alonso de Cordoba 3107, Santiago, Chile

E-mail contact: persi@rm.iasf.cnr.it

A near- and mid-infrared study of the star formation complex G9.62+0.19 is presented. It includes photometrically calibrated images through wide-band $JHK$ and narrow-band Br$\gamma$, $H_2$ and 12.5 $\mu$m filters. These were taken at Las Campanas, La Silla and OAN-San Pedro Mártir. We found evidence of two embedded young clusters of O-B5 stars associated with the radio components B and C, one compact and one ultracompact HII region. The data suggest the presence of a third, more dispersed cluster of more luminous infrared stars at the southern edge of the cloud complex. A large fraction of the stars members of each cluster exhibit significant infrared excess. We confirm the detection of a very red near- and mid-infrared source immersed in the molecular hot core (component F). An $H_2$, shocked gas knot, probably an obscured Herbig-Haro object, was found associated to the blue-shifted lobe of the high-velocity molecular outflow in this core. The properties of the individual sources are discussed in detail.

Accepted by Astronomy & Astrophysics.

## Molecular gas freeze-out in the pre-stellar core L1689B

**M.P. Redman[1], J.M.C. Rawlings[1], D.J. Nutter[2], D. Ward-Thompson[2] & D.A. Williams[1]**

[1] Department of Physics & Astronomy, University College London, Gower Street, London WC1E 6BT, UK
[2] Department of Physics and Astronomy, Cardiff University, PO Box 913, Cardiff CF2 3YB, UK

E-mail contact: mpr@star.ucl.ac.uk

$C^{17}O$ $J = 2 \rightarrow 1$ observations have been carried out towards the pre-stellar core L1689B. By comparing the relative strengths of the hyperfine components of this line, the emission is shown to be optically thin. This allows accurate CO column densities to be determined and, for reference, this calculation is described in detail. The hydrogen column densities that these measurements imply are substantially smaller than those calculated from SCUBA dust emission data. Furthermore, the $C^{17}O$ $J = 2 \rightarrow 1$ column densities are approximately constant across L1689B whereas the SCUBA column densities are peaked towards the centre. The most likely explanation is that CO is depleted from the central regions of L1689B. Simple models of pre-stellar cores with an inner depleted region are compared with the results. This enables the magnitude of the CO depletion to be quantified and also allows the spatial extent of the freeze-out to be firmly established. We estimate that within about 5000 AU of the centre of L1689B, over 90% of the CO has frozen onto grains. This level of depletion can only be achieved after a duration that is at least comparable to the free-fall timescale.

Accepted by MNRAS letters

http://xxx.lanl.gov/abs/astro-ph/0210294

## Structure of the Mid-Infrared Emitting Disk Around WL16

**Michael E. Ressler[1] and Mary Barsony[2]**

[1] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA
[2] Space Science Institute, 3100 Marine Street, Suite A353, Boulder, CO 80303, USA

E-mail contact: Michael.E.Ressler@jpl.nasa.gov

WL16 is a unique member of the young embedded stellar population in the nearby $\rho$ Ophiuchi cloud core: its extended, high surface brightness disk is visible only at mid-infrared wavelengths. We present diffraction-limited images, from 7.9 to 24.5 $\mu$m, of WL16 acquired at the Keck II telescope. We take advantage of the $\sim$0.3$''$ angular resolution of the mid-infrared images to derive physical parameters for the central object by self-consistently combining them with available near-infrared spectroscopy, point-spread-function fit photometry, and pre-main-sequence evolutionary tracks. We find the central star to be a 250 $L_\odot$, 4 $M_\odot$, Herbig Ae star, seen through foreground material of the $\rho$ Oph cloud core that provides an extinction of $A_V = 31 \pm 1$ magnitudes. WL16's disk is detected through all nine observed passbands, not only those four which sample PAH emission features. We confirm, therefore, that the emitting particles are composed of both polycyclic aromatic hydrocarbons (PAHs) and very small (5–100 Å) graphitic grains (VSGs). The disk size as observed through the four PAH filters is $7'' \times 3.5''$, corresponding to a disk diameter of $\sim$ 900 AU. The disk's major axis is at a position angle of $60^\circ \pm 2^\circ$ and viewed at an inclination angle of $62.2^\circ \pm 0.4^\circ$ to our line-of-sight. Our derived inclination angle is in excellent agreement with the previously inferred inclination for the inner disk ($R \leq 30$ $R_\odot$) from kinematic modeling of the near-infrared spectral lines of CO. We can distinguish structure within the PAH disk at unprecedented resolution. We confirm a resolved (1.5$''$ diameter) core component at 7.9 and 8.8 $\mu$m, due to emission from positively charged PAHs. An enhancement in the emission at 12.5 $\mu$m at the disk's edges is found for the first time, and signals the presence of larger ($\geq$ 50–80 carbon atoms) PAHs and/or more hydrogenated PAHs than those found in the bulk of the disk. We find a disk asymmetry, observed at all nine mid-infrared wavelengths, at projected radii 1$''$–2.5$''$ (corresponding to 125 AU $\leq r \leq$ 300 AU) from the central source.

Accepted by Ap.J.

http://arxiv.org/abs/astro-ph/0211155

## The effect of cooling on the global stability of self-gravitating protoplanetary discs

**W.K.M. Rice[1], P.J. Armitage[2,3] M.R. Bate[4] and I.A. Bonnell[1]**

[1] School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews, KY16 9SS, Scotland
[2] JILA, Campus Box 440, University of Colorado, Boulder CO 80309-0440, USA
[3] Department of Astrophysical and Planetary Sciences, University of Colorado, Boulder CO 80309-0391, USA
[4] School of Physics, University of Exeter, Stocker Road, Exeter EX4 4QL, UK.

E-mail contact: wkmr@st-andrews.ac.uk

Using a local model Gammie (2001) has shown that accretion discs with cooling times $t_{\rm cool} \leq 3\Omega^{-1}$ fragment into gravitationally bound objects, while those with cooling times $t_{\rm cool} > 3\Omega^{-1}$ evolve into a quasi-steady state. We use three-dimensional smoothed particle hydrodynamic simulations of protoplanetary accretion discs to test if the local results hold globally. We find that for disc masses appropriate for T Tauri discs, the fragmentation boundary still occurs at a cooling time close to $t_{\rm cool} = 3\Omega^{-1}$. For more massive discs, which are likely to be present at an earlier stage of the star formation process, fragmentation occurs for longer cooling times, but still within a factor of two of that predicted using a local model. These results have implications not only for planet formation in protoplanetary discs and star formation in AGN discs, but also for the redistribution of angular momentum which could be driven by the presence of relatively massive objects within the accretion disc.

Accepted by MNRAS

http://star-www.st-and.ac.uk/astronomy/Welcome

## The Instability of Fast Shocks in Molecular Clouds

**Michael D. Smith[1] and Alexander Rosen[1]**

[1] Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland, U.K.

E-mail contact: mds@star.arm.ac.uk, rar@star.arm.ac.uk

We report on the discovery that moderately fast shocks in dense molecular clouds with low transverse magnetic fields are likely to be unstable. The instability is triggered by the promoted cooling which results from the formation of carbon monoxide and water molecules in an extended warm shock section. Numerical methods are employed to demonstrate that, in the absence of magnetic fields, the instability regime is restricted to densities above $n_o = 10^4\,cm^{-3}$, velocities between $30 - 70\,km\,s^{-1}$, and O or C abundances above $\sim 10^{-4}$, so that cooling from reforming molecules dominates in the warm gas without being suppressed by UV dissociation. The result is either a quasi-periodic or chaotic collapse and re-establishment of the warm shock layer on a typical timescale of $10^6\ cm^{-3}/n_o$ yr with variations on shorter timescales and changes in period possible. Infrared emission lines from the unstable region, including the $H_2$ lines, exhibit orders of magnitude variability. Atomic lines such as H$\alpha$ display constant fluxes but undergo rapid radial velocity variations.

Accepted by MNRAS

Preprints: http://star.arm.ac.uk/~rar/catinst/

## Anatomy of the HH 7 bow shock

**Michael D. Smith[1], Tigran Khanzadyan[1] and Christopher J. Davis[2]**

[1] Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland, U.K.

[2] Joint Astronomy Centre, 660 N. Aʻohōkū Place, University Park, Hilo, Hawaii 96720, USA

E-mail contact: mds@star.arm.ac.uk, tig@star.arm.ac.uk, c.davis@jach.hawaii.edu

We perform a detailed shock diagnosis of HH 7, a well-defined bow shock from a protostellar outflow. We first present molecular hydrogen images in the 2–1 S(1) and 1–0 S(1) K-band emission lines. We then introduce revised models for MHD bow shocks which incorporate a limited C and O chemistry and which account for the shock thickness. We employ these models to interpret the new images as well as ISO data, the line profile, $H_2$ position-velocity diagram, optical images and the proper motion. This yields a C-shock model which satisfies the constraints, confirming that ambipolar diffusion is the linchpin in the shock physics. The best model is a slow-moving paraboloidal bow of speed 55 km $s^{-1}$, with a pre-shock density of $8{\times}10^3$ $cm^{-3}$ and an $H_2$/H number ratio of just 0.25. The bow moves at an angle of $\sim 30°$ to the line of sight and at a position angle of $\sim 95°$ in the plane of the sky rather than along the outflow axis of $\sim 123°$. The bow model also predicts the observed low line emission from $H_2O$, without the need for gas phase depletion. Predictions for imaging and spectroscopy at far infrared wavelengths, employing the 63$\mu$m [OI] line, are presented.

Accepted by MNRAS

Preprints: http://star.arm.ac.uk/~mds/Papers/2002papers.html

## $H^{13}CO^+$ and $CH_3OH$ Line Observations of Pre-stellar Dense Cores in the TMC-1C Region II. Internal Structure

**Shigehisa Takakuwa[1,2], Takeshi Kamazaki[3], Masao Saito[4], and Naomi Hirano[1]**

[1] Academia Sinica Institute of Astronomy and Astrophysics, P.O. Box 23-141, Taipei 106, Taiwan

[2] Present address: Harvard-Smithsonian Center for Astrophysics, 82 Pu'uhonu Place, Suite 210, Hilo, HI 96720, U.S.A.

[3] Nobeyama Radio Observatory, National Astronomical Observatory, Nobeyama, Minamimaki, Minamisaku, Nagano 384-1305, Japan

[4] National Astronomical Observatory, Osawa 2-21-1, Mitaka, Tokyo 181-8588, Japan

E-mail contact: stakakuwa@sma.hawaii.edu

We have carried out the detailed $H^{13}CO^+$ ($J$=1–0) and $CH_3OH$ ($J_K$=$2_0$–$1_0$ $A^+$) observations of two dense cores in the TMC-1C region with the 45 m telescope at Nobeyama Radio Observatory and the Nobeyama Millimeter Array (NMA). These two cores, $H^{13}CO^+$ core 2 and $CH_3OH$ core 6, are identified previously by the $H^{13}CO^+$ and $CH_3OH$ mapping observations of the entire TMC-1C region, and show no sign of protostar formation. We found that the internal structure of the $H^{13}CO^+$ core 2 is different from that of cores with Class 0 protostars; this core consists of three velocity components and shows the radial column density distribution of $\sim r^{-0.43\pm0.08}$, which is flatter than that in the protostellar cores ($\sim r^{-1.0}$). The internal structure of the $CH_3OH$ core 6 is different from that of the $H^{13}CO^+$ core 2; the combined images of the 45 m and NMA data have revealed that there are three smaller-scale $CH_3OH$ "clumps" $\sim$ 2500 AU in size inside this core. The mass of the small-scale clumps, $\sim 0.02$ $M_\odot$, is much smaller than the virial mass ($\sim 0.3$ $M_\odot$), suggesting that these clumps are gravitationally unbound. The velocity dispersion observed in these small-scale clumps is 0.45 - 0.5 km $s^{-1}$, which is comparable to that of clumps with 0.02 - 0.03 pc in radius. A comparison of the velocity dispersion of the small-scale clumps and that of larger scale cores suggests that the velocity dispersion that follows the power-law in the radius larger than $\sim$ 0.02 - 0.03 pc turns into constant value of $\sim$ 0.45 - 0.5 km $s^{-1}$ in the smaller size scale. The mass-size relation of the pre-stellar gas structures suggests that they follow the trend of constant gas density ($\sim 10^5$ $cm^{-3}$) in the radius from 0.006 pc to $\sim$ 0.3 pc, and that the smaller scale structures tend to be gravitationally unbound. The presence of the small clumps with sub-stellar masses in pre-stellar cores implies that coalescence processes are likely to play an important role in forming protostars inside the cores. The observational difference of the internal structures among the $CH_3OH$ core 6, $H^{13}CO^+$ core 2, and protostellar cores might represent the difference of the evolutionary stages.

Accepted by Astrophysical J.

http://www.asiaa.sinica.edu.tw/takakuwa/NMApaper/

## A Spectro-astrometric study of southern pre-main sequence stars — binaries, outflows, and disc structure down to AU scales

**Michihiro Takami[1], Jeremy Bailey[2] and Antonio Chrysostomou[1]**

[1] Department of Physical Sciences, University of Hertfordshire, Hatfield, Herts AL10 9AB, UK

[2] Anglo-Australian Observatory, PO Box 296, Epping, NSW 1710, Australia

E-mail contact: takami@star.herts.ac.uk

spectro-astrometric observations for 28 southern pre-main sequence (PMS) stars and investigate their circumstellar environment down to AU scales. The structures detected in the "position spectra" include: (1) almost all the known binary companions in our sample (Sz 68, Sz 41, HO Lup, VW Cha, S CrA, AS 205), (2) companion candidates which have not been detected by infrared speckle techniques (T CrA, MWC 300), (3) monopolar and bipolar jets (AS 353A, CS Cha), (4) a combination of jets and a bow shock (VV CrA), and (5) a combination of a jet and stellar companion (R CrA). Results in known binaries show that this technique is capable of detecting binaries with separations down to ∼10 milliarcsec. Both components in each binary appear to have strikingly similar profiles in Hα emission, indicating a similarity of circumstellar activity (mass accretion and/or a wind), and supporting the scenario of core fragmentation for the mechanism of binary formation. The bipolar Hα jet in CS Cha has a spatial scale of ∼1.5 AU, similar to that previously observed in RU Lup, and likely be heated by a mechanism other than shocks. From the spatial scale, velocity, and Hα luminosity, we estimate the mean hydrogen density in the AU-scale bipolar flows to be $\geq 10^7$ $cm^{-3}$. The bipolar geometry in these jets can be explained by the presence of a disc gap/hole at AU scales, which could be induced by a gas-giant planet at the ice condensation radius.

Accepted by Astronomy & Astrophysics

http://xxx.lanl.gov/abs/astro-ph/0210559

## Imaging study of NGC 3372, The Carina Nebula. I: $UBVRIJHK$ photometry of Tr 14, Tr 15, Tr 16 and Car I

**M. Tapia[1], M. Roth[2], R.A. Vázquez[3] and A. Feinstein[3]**

[1] Instituto de Astronomía, UNAM, Apdo. Postal 877, 2800, Ensenada B.C., Mexico

[2] Las Campanas Observatory, Carnegie Institution of Washington, La Serena, Chile

[3] Fac. de Ciencias Astronómicas y Geofísicas, U. N. La Plata, IALP-CONICET, La Plata, Argentina

E-mail contact: mt@astrosen.unam.mx

Results are presented of a large-scale imaging photometric study of the stellar population in the northern part of NGC 3372 in the $UBVRIJHK$ bands with a wavelength coverage from 0.33 to 2.5 $\mu$m. The observations were made at Las Campanas Observatory. The optical CCD mosaics cover an area approximately of 32 × 22 square arcminutes centred between the Tr 14 and Tr 16 clusters. The survey was extended to cover 12 × 12 square arcminutes at the location of Tr 15. Near-infrared NICMOS3 mosaics covering the areas occupied by these clusters were obtained in the $JHK$ photometric bands. By means of star counts in $V$, the centres and sizes of each cluster were redetermined yielding: Tr 14 ($r = 264$ arcsec), Tr 15 ($r = 320$ arcsec) and Tr 16 ($r = 320$ arcsec). It was confirmed that Cr 232 is not a true cluster. Multicolour optical photometry was obtained for 4152 stars. Two colour and colour-magnitude diagrams are presented and analyzed for each individual cluster and compared to those of the field. The widespread variations in the dust density and also in the dust size distribution leading to widely different values of $A_V$ and reddening laws towards Tr 14 and Tr 16 are confirmed. No spatial patterns were found for these variations. Spectroscopic parallaxes were computed and the results are consistent with all three clusters being at similar distance from the Sun ($< d >= 2.7$ kpc) but the data showed very large scatter in both $A_V$ and $d$. Analyses of the extinction-corrected colour-magnitude diagrams suggest ages between 3 and 60 million years for the stars in Tr 15 and between less than 1 and 6 million years for Tr 14 and Tr 16. A small number of infrared-excess stars were found in Tr 16 and Tr 14 but not in Tr 15. The distribution of stars in Tr 14 seen in the near-infrared suggests that this cluster is partially embedded in a molecular cloud. This molecular cloud extends towards the west reaching its highest density, marked by a CO peak emission, some three arcmin to the southwest of the nucleus of Tr14. The rich UV field created by the Tr14 stars ionizes most of the visible HII region in its vicinity and most of the radio HII region Car I. Evidence is found of ionization fronts leading into the molecular cloud, which appears to be "wrapping" the Tr 14 cluster. Deep $JHK$ images of the Car I region reveal the presence of an embedded stellar population illuminating a large infrared reflection nebula. It includes at least one O9–B0 star associated with an ultracompact HII region. Nebulous 2.2 $\mu$m emission from three of the mid-infrared sources in the Tr 14 region is also found.

Accepted by MNRAS

## Axi-symmetric models of ultraviolet radiative transfer with applications to circumstellar disk chemistry

**Gerd-Jan van Zadelhoff[1], Yuri Aikawa[2], M.R. Hogerheijde[3] and Ewine F. van Dishoeck[1]**

[1] Leiden Observatory, P.O. Box 9513, 2300 RA Leiden, The Netherlands

[2] Dept. of Earth and Planetary Sciences, Kobe University, 1-1 Rokkoudai, Nada-ku, Kobe, 657-8501, Japan

[3] Steward Observatory, The University of Arizona, 933 N. Cherry Ave. Tucson AZ, USA

E-mail contact: zadelhof@knmi.nl

A new two-dimensional axi-symmetric ultraviolet radiative transfer code is presented, which is used to calculate photodissociation and ionization rates for use in chemistry models of flaring circumstellar disks. Scattering and absorption of photons from the central star and from the interstellar radiation field are taken into account. The molecules are effectively photodissociated in the surface layer of the disk, but can exist in the intermediate, moderately warm layers. A comparison has been made with an approximate 2D ray-tracing method and it was found that the latter underestimates the ultraviolet field and thus the molecular photodissociation rates below the disk surface. The full 2D results show significantly higher abundances of radicals such as CN and $C_2H$ than previous work, partly due to the fact that CO is dissociated to greater depths. Results for different stellar radiation fields are also presented. The CN/HCN ratio shows a strong dependence on the stellar spectrum, whereas other ratios such as $HCO^+$/CO show only little variation.

Accepted by A&A

http://arXiv.org/abs/astro-ph/0211014

## Tracing the Mass during Low-Mass Star Formation, IV: Observations and Modeling of the Submillimeter Continuum Emission from Class I Protostars

**C.H. Young[1], Y.L. Shirley[1], N.J. Evans II[1] and J.M.C. Rawlings[2]**

[1] Department of Astronomy, The University of Texas at Austin, Austin, Texas 78712–1083, USA

[2] Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT E-mail contact: cyoung@astro.as.utexas.edu

We present results from the observations and modeling of seventeen Class I cores with the Submillimetre Common Users Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope (JCMT). Our sample consists of cores with

$64 < T_{bol}(K) < 270$, $0.2 < L_{obs}/L_\odot < 12$, and $50 < L_{obs}/L_{smm} < 1000$. By modeling the transfer of radiation through the envelope for nine cores, we find, for a power law distribution $n(r) = n_f(r/r_f)^{-p}$, the average and standard deviation $\langle p \rangle = 1.6 \pm 0.4$ and a median of $p = 1.8$. However, the inclusion of a disk or other point-like component can cause the derived $p$ to be shallower by as much as 0.5. We discuss uncertainties due to the interstellar radiation field (ISRF), disks, dust opacity, and outer radii in our modeling results. We find no evidence for a truncated outer radius or radially variant dust properties in most sources. Uncertainty in the strength of the ISRF and possible existence of a disk contribute the greatest uncertainty in $p$. In addition, we test the Shu collapse model for our sources and discuss the application of simpler analyses that derive a density power law distribution directly from the slope of the intensity radial profile. The total mass of the envelope in our sample has a range of $0.04 < M_{env}/M_\odot < 5.0$, but these masses disagree with the virial masses derived from molecular line observations, indicating that observations of molecular lines do not trace the mass in some Class I cores. We also discuss several sources individually. In particular, IRAS 03256+3055, with its unique morphology, is an ideal object for testing theories of fragmentation in the formation of low-mass protostars. Also, we note the possibility, through some simple calculations, that IRAS 04385+2550 is a young, forming substellar object. Finally, we discuss the nature of these sources in light of various evolutionary indicators and find that $T_{bol}$ and $L_{obs}/L_{smm}$ are often inconsistent in distinguishing Class 0 from Class I cores. We note that, in this sample, the $L_{obs}/L_{smm}$ criterion redefines many of these Class I sources (by $T_{bol}$) as Class 0 sources.

Accepted by Astrophysical Journal Supplements

Preprints at http://peggysue.as.utexas.edu/cyoung/

## OH (1720 MHz) Masers and Mixed-Morphology Supernova Remnants

**F. Yusef-Zadeh[1], M. Wardle[2], J. Rho[3] & M. Sakano[4]**

[1] Dept of Physics and Astronomy, Northwestern Univ., Evanston, IL 60208, USA
[2] Department of Physics, Macquarie University, NSW 2109, Australia
[3] SIRTF Science Center, California Institute of Technology, MS 220-6, CA 91125, USA
[4] Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK

E-mail contact: zadeh@northwestern.edu

Radio surveys of supernova remnants (SNRs) in the Galaxy have uncovered 19 SNRs accompanied by OH maser emission at 1720 MHz. This unusual class of maser sources is suggested to be produced behind a shock front from the expansion of a supernova remnant running into a molecular cloud. An important ingredient of this model is that X-ray emission from the remnant enhances the production of OH molecule. The role of X-ray emission from maser emitting (ME) SNRs is investigated by comparing the X-ray induced ionization rate with theory. One aspect of this model is verified: there is a strong association between maser emitting and mixed-morphology (MM) or thermal composite SNRs –center-filled thermal X-ray emission surrounded by shell-like radio morphology. We also present ROSAT and ASCA observations of two maser emitting SNRs: G21.8–0.6 (Kes 69) and G357.7–0.1 (Tornado).

Accepted by ApJ

# The secret life of adolescent stars: magnetic activity of Post-T Tauri stars in Lindroos systems

**Nuria Huélamo**

Thesis work conducted at: MPE Garching, Germany

Current address: European Southern Observatory, Casilla 19001, Santiago 19, Chile

Electronic mail: nhuelamo@eso.org

Ph.D dissertation directed by: Dr. Ralph Neuhäuser

Ph.D degree awarded: October 2002

This thesis presents an analysis of the magnetic activity displayed by a sample of pre-main sequence (PMS) late-type stars in the Post-T Tauri phase. The sample contains Post-T Tauri stars (PTTS) found in Lindroos systems, which are defined as high mass-ratio binary systems with early-type primaries (mostly B-type stars) and later-type secondaries. The ages of PTTS are intermediate between the oldest Classical T Tauri stars and the youngest dwarf stars in Zero-Age main-sequence (ZAMS) clusters. We have focused our study on the X-ray and rotational properties of PTTS, given that both are connected with the magnetic activity observed in late-type stars.

The analysis of the ROSAT X-ray data has shown that PTTS are strong and hard X-ray emitters, displaying levels of magnetic activity comparable to those of younger objects. We have even detected an energetic flare from one of the PTTS, very similar to those observed in T Tauri stars. On the other hand, the optical monitoring of the PTTS has allowed us to derive their rotation periods. Given that the sample is not X-ray selected, we can study the rotational properties of PTTS without being biased towards fast rotators. Lindroos PTTS display periods between 2 and 8 days. The comparison of the derived periods with theoretical models of angular momentum evolution of PMS late-type stars shows that the rotational properties of PTTS can be explained if the magnetic decoupling of the star-disk system occurs between 1 Myr and 20 Myr. Given that these ages are directly related with the lifetime of circumstellar disks, that range provides an estimation of the dissipation timescale of protoplanetary disks.

The study of activity-rotation relations in PTTS have shown that they display high levels of magnetic activity that decreases very steeply for the slowest rotators. In fact, the activity parameters studied are systematically stronger for fast rotating stars and, in all cases, a small variation in the rotation period gives rise to a large variation in the activity indicator. The analysis of the activity-rotation-age relations has allowed us to trace the evolution of the magnetic activity in PMS late-type stars, from the T Tauri phase until their arrival on the main sequence. PTTS seem to be as active as T Tauri stars, which could be the result of the predicted spin-up of PMS late-type stars as they contract to the MS.

Finally, this work has also helped to shed light on the intriguing X-ray emission from late B-type stars. Although these stars are not supposed to be X-ray emitters, we have reported a strong and hard X-ray emission from three Lindroos B-type primaries. Given that their X-ray properties are similar to those of the Lindroos late-type secondaries, we have concluded that they may probably have unresolved late-type companions responsible of the X-ray emission. Diffraction-limited infrared observations of the three Lindroos B-type stars have confirmed this hypothesis for one of the stars. The other two sources need to be confirmed as spectroscopic binaries.

# Observational tests for self-gravitating accretion disks

**Giuseppe Lodato**

Thesis work conducted at: Scuola Normale Superiore, Pisa, Italy

Current address: Scuola Normale Superiore, Piazza dei Cavalieri, 7, I-56126, Pisa, Italy.

Address as of November 2002: Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge. CB3 0HA, United Kingdom.

Electronic mail: lodato@sns.it

Ph.D dissertation directed by: Prof. Giuseppe Bertin

Ph.D degree awarded: October 2002

Under appropriate circumstances, the disk self-gravity can change significantly the general scenario and the physical processes that occur in accretion disks. In particular, the gravitational instabilities that arise in self-gravitating disks can participate not only in the angular momentum but also in the energy transport inside the disk. This Thesis investigates the effects of the disk self-gravity on the observed properties of accretion disks. Here, I present the results of a semi-empirical approach that leads to the construction of a steady state model of self-gravitating disks, in which, on the one hand, the $\alpha$-prescription for viscosity is maintained, and, on the other hand, the energy balance equation is corrected so that self-regulation with respect to gravitational instabilities is properly incorporated, a natural requirement for self-gravitating disks. Deviations from Keplerian rotation are properly taken into account by self-consistently solving the Poisson equation.

The simple statement of self-regulation (in the form $Q \approx 1$) is sufficient for the characterization of the dynamical properties of the disk, in particular, of its rotation curve. This leads to an immediate application to observations directly related to kinematics. In this Thesis I discuss how the disk self-gravity can modify: (*i*) The shape of global line profiles emitted by protostellar disks, referring to the context of FU Orionis objects. Changes in the shape of the long-wavelength line profiles (for example $H_2$ rotational lines and sub-millimeter CO emission lines), associated with the effect of the disk self-gravity, should be detectable with currently available observational techniques. On the other hand, the line profiles at shorter wavelengths are less influenced by the disk self-gravity, because they are produced in the inner Keplerian regions of the disk. The combined use of short wavelength lines (that probe the inner disk structure) and of long wavelength lines (that probe the outer disk structure) can therefore be used to determine the importance of the disk self-gravity in Young Stellar Objects. (*ii*) The rotation curve of some AGN disks. In the Thesis, I focus on the Seyfert galaxy NGC 1068. Water maser emission on the pc scale has shown that the rotation curve of the nuclear disk falls off less steeply than Keplerian. The model presented in the Thesis can indeed fit the available kinematical data of NGC 1068 and explain the shape of the rotation curve with a disk mass comparable to the mass of the central black hole. An interesting by-product of the modeling procedure is a determination of the value of the viscosity parameter $\alpha$.

To address the issue of the emission properties of self-gravitating disks, a thorough discussion of the energy balance is needed. This has led me to consider the thermal stability of the models. The anomalous heating term, included in the energy balance equation to ensure that self-regulation properly occurs, modifies the thermal stability properties of the disk, so that I find that a self-gravitating disk can be thermally stable, even when the cooling mechanism is optically thin *bremsstrahlung*.

Probably the best diagnostic tool to test the structure of Young Stellar Objects is given by the observed SEDs. By fitting the observed SED of a sample of YSOs with the self-gravitating disk models presented in the Thesis, I find that the SED of FU Orionis objects is well explained, without the additional contribution of an infalling envelope, often invoked to explain the long-wavelength SED. The required accretion rates resulting from the fit are not different from previous analyses. In fact, I find $\dot{M} \approx 10^{-5} - 10^{-4} M_{\odot}/\mathrm{yr}$. The disk mass required by the self-gravitating disk picture is not as high as previously argued based on models without the anaomalous heating term and turns out to be comparable to the central object mass. These results may indeed be a clue that FU Orionis objects are less evolved than the quiescent T Tauri stars.

## *New Jobs*

### Two Postdoctoral Positions in Origin of Planetary Systems - Stockholm University

Two postdoctoral Research Associate positions in astrophysics of planetary system formation at Stockholm Observatory (Department of Astronomy, Stockholm University, Sweden) are available. While both positions are mostly theoretical/computational, candidates combining theory and observations may also apply.

The first position is a part of a new European Research Training Network "The Origin of Planetary Systems", with 8 nodes located in Geneva, Heidelberg, Leiden, London, Paris, Stockholm and Warsaw. Network activities, such as conferences and collaborative visits, will be supported. We seek an astrophysicist below 36 years of age, a national or resident of European Union except Sweden, or of an EU-associated state (e.g., Switzerland, East European applicants to EU, Israel). The successful candidate will model the dynamics and interpret the observations of debris disks, study extrasolar planet formation in self-gravitating, multidimensional solar nebulae models, and/or investigate migration, growth, and eccentricity evolution of protoplanets in disks. Starting date can range from Dec. 2002 to Spring of 2003. The salary covers 2.5 years at 2700 Euro per month.

The second position is funded for 2 years by the Swedish Science Research Council (VR). The successful candidate will be free to conduct either basic research or more object-specific modeling of extrasolar systems with disks. We seek a candidate with strong astrophysical and computational background, eager to enter new, rapidly developing fields. This position is for non-Swedish candidates holding a PhD awarded after 1998, with exceptions due to special circumstances. The monthly salary will be 25,000 SEK per month, or 2700 EUR/month ($32400 per year). The earliest starting date is January 2003.

Stockholm Observatory is a leading Swedish astronomy center (http://www.astro.su.se/). The Planetary Systems Formation group provides excellent computing facilities (i.a., a Beowulf cluster with Gigabit interconnect). For more information on the host institution, the European Network, and its eligibility criteria please visit
http://www.astro.su.se/~pawel/netwrk/postdocs.html.

Application should include: Curriculum Vitae, list of publications, statement of research interests, and a minimum of three names and e-mail addresses of scientists familiar with the candidate. We encourage submission via Web pages, email, or fax. Selection of candidates will start 30 Nov. 2002, and continue until positions are filled.

STOCKHOLM OBSERVATORY, STOCKHOLM UNIVERSITY
SE-10691, Stockholm
Sweden

Tel: +46-855378549
FAX: +46-855378510
Email Submission Address: pawel@astro.su.se
Email Inquiries: pawel@astro.su.se
URL: http://www.astro.su.se/~pawel/netwrk/postdocs.html

Attention: Pawel Artymowicz, Assoc. Prof.

## Postdoctoral Position (09/02) at the Max-Planck-Institut für Astronomie (MPIA)
### Heidelberg, Germany

The MPIA department "Star and Planet Formation" (Head: Thomas Henning) invites applications for a qualified candidate in the field of planet searches with astrometric or transit methods. We expect that the successful candidate actively develops an own program for exoplanet detections. The position is initially for 2 years and can be extended up to 5 years. The MPIA is preparing to use VLTI as an astrometric facility and considers joining a transit network.

The MPIA coordinates the European Network "Extrasolar Planets" and is actively involved in the definition of a Planet Finder for the VLT. In addition, we have an active AO group and an interferometry group which is involved in the use of the AO system NACO at the VLT and the VLT Interferometer, respectively.

The MPIA operates the Calar Alto Observatory (http://www.mpia.de/Public/CAHA/index.html) with its 2.2m and 3.5m telescopes, which have a broad suite of optical and infrared instruments. The MPIA is heading a number of cutting-edge instrument developments for the VLT and LBT telescopes that will be ready for scientific use in the next years. The institute also operates the ISOPHOT Data Center in Heidelberg, is a partner in the LBT Project, and is one of the two German partner institutes in the Sloan Digital Sky Survey. In addition to its general computing facilities, the MPIA offers special computers for theoretical research including an ORIGIN 2000 system and a cluster of special hardware devices (GRAPE) connected to local PC clusters. It has access to a parallel CRAY T3E-600 and a vector NEC SX-4B supercomputer at the MPP Computing Center near Munich.

The position is available on the German BAT scale (BAT IIa). The successful candidate is expected to carry out observational research programs and will have full access to both the MPIA's computing facilities and to the observational facilities at the Calar Alto Observatory; further, she/he will have full access to ESO's VLT and La Silla facilities. Candidates may be asked to devote a modest fraction of their time to functional duties.

Applicants should have a PhD in astronomy, physics, or related field by the start of the appointment. The position may commence as early as possible. The application should describe research experience and interests, and should include a complete curriculum vitae and bibliography. Three letters of recommendation should be sent directly to the address below. Application materials should be sent no later than January , 31, 2003. Questions regarding the research opportunities at the MPIA can be directed to Prof. Dr. Thomas Henning (henning@mpia.de).

Max-Planck-Institut für Astronomie
Attn.: Mrs. Maria Janssen-Bennynck
Königsstuhl 17
D-69117 Heidelberg, Germany

The Max Planck Society is an equal opportunity employer and particularly encourages applications from women and disabled persons. Further information can be found on the Website: http://www.mpia.de

## Pre- and Postdoctoral Positions (10/02)

### Max-Planck-Institut für Astronomie (MPIA) Heidelberg, Germany

Several pre-and postdoctoral positions are available within the newly established European Research Training Network on The Origin of Planetary Systems. The network combines the following astronomical institutions in Europe working in the field of planet formation:

Max-Planck-Institut für Astronomie, Andreas Burkert (Network Coordinator), burkert@mpia-hd.mpg.de, and Thomas Henning, henning@mpia.de
Stockholm Observatory, Pawel Artymowicz, pawel@astro.su.se
Queen Mary & Westfield College, Richard Nelson, R.P.Nelson@qmw.ac.uk
University of Leiden, Ewine van Dishoeck, ewine@strw.leidenuniv.nl
University of Geneva, Michel Mayor, Michel.Mayor@obs.unige.ch
Institute d'Astrophysique de Paris, Claude Bertout, bertout@iap.fr
Nikolaus Copernicus Astronomical Centre, Poland, Michal Rozyczka, mnr@camk.edu.pl

The network's principal aim is to carry out in a concerted effort a comprehensive set of observational and theoretical studies of the formation of gas-rich disks around central stars, their subsequent viscous evolution, the agglomeration of dust particles in disks to planetary embryos and massive Jovian planets, as well as planet migration and the formation of stable planetary systems. The appointed researchers will have access to unique observational facilities and instruments. They will get rigorous training in laboratory physics and computational physics using special purpose hardware boards and on data reduction with special focus on the data from the Space Infrared Telescope Facility.

As part of the program pre- and postdoctoral positions will be available starting November 2002 or later. According to the rules of the network programme, the posts are open only to nationals of a European Union country and associated states other than that in which the post is held. See http://www.cordis.le/fp5/management/particip/v-gfpbox4.htm BOX4 for an updated list of associated states. Applicants should be under 36 years of age and should not have been resident in the country where they propose to work for more than 18 months on the two years before the start of the post. A competitive salary will be paid at each institution in accordance with local regulations, including money for extended visits of other nodes and conferences. The appointments will be for a maximum of 3 years. In order to enhance mobility and collaboration the network researchers will be encouraged to spend a couple of months at other network institutes during the course of their appointments. Applications should include a curriculum vitae, a publication list, a summary of current research interests and a list of institutes or topics related to the main topic of the network which they would prefer to work. Please arrange for 2 letters of reference. The review of applications will start at the beginning of December 2002 and will continue till all the positions are filled. Questions regarding the research can be directed to Priv. Doz. Dr. Andreas Burkert (burkert@mpia.de), Phone +49 6221 528226. Application materials should be sent to:

Max-Planck-Institut für Astronomie
attn. Mrs. Hannelore Heissler
Königstuhl 17 D-69117 Heidelberg Germany E-mail: heissler@mpia-hd.mpg.de,
phone: (+49) 6221 528285,
Fax: (+49) 6221 528246

The Max Planck Society is an equal opportunity employer and particularly encourages applications from women and disabled persons. Further information can be found on the Website: http://www.mpia.de

## Magnetic Fields and Star Formation: Theory versus Observations

**April 21st-25th , 2003**
**Madrid (Spain)**

Aims:

Magnetic fields play a key role in the physics of star formation at all scales: from the formation of the large complexes of molecular clouds to the channelling of the accretion flow onto pre-main sequence stars. The plasma physics required to solve these problems is non-linear and very complex requiring the development of large numerical codes as well as analytical studies of a well selected sample of enlightening problems. An additional difficulty is that the detection and study of magnetic fields is not easy from the observational point of view and, therefore, theoretical models cannot be easily constrained. The aim of this workshop is to join theoretical and observational efforts to define a set of relevant problems for the physics of star formation that can be properly studied with the current or near future instruments.

(see http://www.oan.es/MFSF/)

SOC:
A.I. Gomez de Castro (chair), R.E. Pudritz, R. Bachiller, J. Cernicharo, T. Montmerle, E. Zweibel, M. Tagger, E. Vazquez-Semadeni, C. Eiroa, C. Ferro-Fontan, J. Torrelles, G. Anglada

LOC:
J. Coloma (Secretary), F. Colomer, A.I. Gomez de Castro, M. Franqueira, J. Santiago, M. Tafalla, E. Verdugo

## Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the Newsletter bounces back from an address for three consecutive months, the address is deleted from the mailing list.

2nd *Eddington* Workshop
"Stellar-structure and habitable planet finding"
April 9 to 11, 2003 – Hotel La Torre, Mondello (Palermo – Italy)
Organized by the
European Space Agency and INAF – Palermo Astronomical Observatory

The *Eddington* mission was approved in May 2002 as part of the European Space Agency's new Science Program "Cosmic Vision" for launch in 2007/8. Its primary goals are extra-solar planet hunting by transits, and the determination of multi-mode oscillations of stars for asteroseismic investigations of stellar structure and evolution. There will also be ample and exciting opportunities for parallel and ancillary science.

In its current design the mission consists of $4 \times 60$ cm folded Schmidt telescopes, each with a 6 deg diameter field of view and its own CCD array camera; its primary data products will be calibrated relative photometric time series for all stars in the field of view down to the instrument's limiting magnitude.

The current observing plan is to spend 3 years continuously on a single target field monitoring upwards of 20 000 late type dwarfs with noise level of $6.3 \times 10^{-5}$ in 1 hour, and upwards of 100 000 stars of all types with lower $S/N$, and 2 years primarily devoted to asteroseismology with 1 to 3 months on different target fields monitoring up to 50 000 stars per field with a noise level in Fourier space $< 1.5$ ppm in 30 days with the goal of determining oscillation frequencies with a precision of 0.1–0.3 $\mu$Hz

**Choosing the Planet Search Field**

The observing program of *Eddington* foresees a long (3 yr) observation on a single field (the "planet field") with the primary aim of terrestrial planet detection. Given the advanced phase of definition of the mission the direction in which the *Eddington* planet field will be located must now be defined. This is essential both because of the impact that this will have on the mission's final design and because of the long lead time which will be required for the ground-based preparatory work on characterizing the stars which will fall in the *Eddington* planet field.

One session of the workshop will mainly be dedicated to the selection of the planet field. We solicit proposals both for specific directions in the sky as well as for required specific characteristics the target field. Presentations (both in oral and in poster form) will be discussed at the workshop.

**The workshop**

This workshop is an invitation to the wider scientific community to get involved in the *Eddington* mission – both the planet finding and asteroseismology phases.

The main topics covered at the workshop will be:

- the mission baseline's and possible options
- selection of the planet field
- possible scientific targets for the asteroseismology part
- possible/required data products for each scientific goal
- "support" science needed to be done by the community ahead of the mission
- parallel and auxiliary science

The program will include a presentation of the various aspects of the mission's present baseline and scientific performance, and an overview of the mission's science goals. Contributions are solicited on all aspects of the mission. A formal call for abstracts will be circulated later this year, together with a preliminary program with a list of invited speakers. An "expression of interest" form can be found at `http://www.astropa.unipa.it/Eddington/Eddi2003.html`, which should be returned to `eddi2003@astropa.unipa.it`. The same email address can also be contacted with any question regarding the workshop. Updated information about the Workshop will be made available at the same web address.

Please feel free to pass this message to any colleague who might be interested in the meeting and who may not be in the initial mailing list. Note that the invitation is equally open to scientists working both in ESA- and non-ESA-member states.

**Scientific Organizing Committee:**

F. Favata (ESA/ESTEC – chair), A. Baglin (Obs. Paris Meudon, FR), C. Catala (Obs. Paris Meudon, FR), J. Christensen-Dalsgaard (Aarhus Univ., DK), M. Di Mauro (INAF - Catania Obs., IT), G. Gilmore (IoA, UK), The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star formation and molecular clouds. You can submit material for the following sections: *Abstracts of recently accepted papers* (only for papers sent to refereed journals, not reviews nor conference notes), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star formation and interstellar medium community), *New Books* (giving details of books relevant for the same community), *New Jobs* (advertising jobs specifically aimed towards persons within our specialty), and *Short Announcements* (where you can inform or request information from the community).

**Latex macros for submitting abstracts and dissertation abstracts are appended to each issue of the newsletter**.

The Star Formation Newsletter is available on the World Wide Web at http://www.ifa.hawaii.edu/∼reipurth or at http://www.eso.org/gen-fac/pubs/starform/ .