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## *Abstracts of recently accepted papers*

### **Protostellar Collapse in a Rotating, Self-Gravitating Sheet**

**Alan P. Boss<sup>1</sup> and Lee W. Hartmann<sup>2</sup>**

<sup>1</sup> DTM, Carnegie Institution of Washington, 5241 Broad Branch Road, NW, Washington, DC 20015-1305, USA

<sup>2</sup> Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

E-mail contact: boss@dtm.ciw.edu

We extend our previous calculations (Hartmann et al. 1994) of the self-gravitational collapse of an initially sheet-like, non-rotating cloud to include rotation at a wide range of initial rates ( $10^{-15}$  rad s<sup>-1</sup> to  $10^{-13}$  rad s<sup>-1</sup>). The  $1 M_{\odot}$  clouds begin in hydrostatic equilibrium, appropriate for a spherical portion of an isothermal, infinite, self-gravitating, flat layer, with symmetry about the midplane. Rotation is assumed to be about an axis perpendicular to the flat layer, allowing the calculations to retain axisymmetry about the rotation axis. The clouds are assumed to remain isothermal during the collapse phase that eventually results from the marginally unstable initial conditions. We find that large-scale infall motions build up during the first several free fall times of evolution prior to the onset of the dynamic collapse phase, leading to subsonic, inward directed motions throughout the sheet, peaking at speeds of  $\sim 0.1$  km s<sup>-1</sup> at radii of  $\sim 2000$  AU. The spherically-averaged, radial density profile of the cloud strongly resembles a Bonnor-Ebert sphere prior to this time, with a density contrast less than the critical ratio prior to the onset of collapse. We also find that rotating sheets collapse to form central protostars surrounded by infalling, large-scale, disk-like envelopes with surface density profiles  $\sigma \propto r^{-1/2}$ .

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Preprint available at <http://www.ciw.edu/boss/ftp/sheet/>

### **Clumpy outer Galaxy molecular clouds and the steepening of the IMF**

**J. Brand<sup>1</sup>, J.G.A. Wouterloot<sup>1,2,3,\*</sup>, A.L. Rudolph<sup>4</sup>, and E.J. de Geus<sup>5,6,‡</sup>**

<sup>1</sup> Istituto di Radioastronomia, CNR, Via Gobetti 101, I-40129 Bologna, Italy

<sup>2</sup> Radioastronomisches Institut, Universität Bonn, Auf dem Hügel 71, D-53121 Bonn, Germany <sup>3</sup> I. Physikalisches Institut, Universität zu Köln, Zùlpicher Straße 77, D-50937 Köln, Germany

<sup>4</sup> Department of Physics, Harvey Mudd College, Claremont, CA 91711, USA

<sup>5</sup> Department of Astronomy, University of Maryland, College Park, MD 20742, USA

<sup>6</sup> Astronomy Department, Caltech, Pasadena, CA 91125, USA

\* Present address: Joint Astronomy Centre, 660 N. A'ohoku Place, University Park, 96720 Hilo, Hawaii, USA

‡ Present address: NFRA, Postbus 2, 7990 AA Dwingeloo, The Netherlands

E-mail contact: brand@ira.bo.cnr.it

We report the results of high-resolution ( $\sim 0.2$  pc) CO(1-0) and CS(2-1) observations of the central regions of three star-forming molecular clouds in the far-outer Galaxy ( $\sim 16$  kpc from the Galactic Center): WB89 85 (Sh 2-127), WB89 380, and WB89 437. We used the BIMA array in combination with IRAM 30-m and NRAO 12-m observations. The GMC's in which the regions are embedded were studied by means of KOSMA 3-m CO(2-1) observations (here we also observed WB89 399). We compare the BIMA maps with optical, radio, and near-infrared observations. Using a clumpfind routine, structures found in the CO and CS emission are subdivided in clumps, the properties of which are

analyzed and compared with newly derived results of previously published single-dish measurements of local clouds (OrionB South and Rosette).

We find that the slopes of the clump mass distributions ( $-1.28$  and  $-1.49$ , for WB89 85 and WB89 380, respectively) are somewhat less steep than found for most local clouds, but similar to those of clouds which have been analyzed with the same clumpfind program.

We investigate the clump stability by using the virial theorem, including all possible contributions (gravity, turbulence, magnetic fields, and pressure due to the interclump gas). It appears that under reasonable assumptions a combination of these forces would render most clumps stable. Comparing only gravity and turbulence, we find that in the far-outer Galaxy clouds, these forces are in equilibrium (virial parameter  $\alpha \approx 1$ ) for clumps down to the lowest masses found (a few  $M_{\odot}$ ). For clumps in the local clouds  $\alpha \approx 1$  only for clumps with masses larger than a few tens of  $M_{\odot}$ . Thus it appears that in these outer Galaxy clumps gravity is the dominant force down to a much lower mass than in local clouds, implying that gravitational collapse and star formation may occur more readily even in the smallest clumps. Although there are some caveats, due to the inhomogeneity of the data used, this might explain the apparently steeper IMF found in the outer Galaxy.

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## Formation of twisted elephant trunks in the Rosette Nebula

Per Carlqvist<sup>1</sup>, Gösta Gahm<sup>2</sup> and Helmuth Kristen<sup>2</sup>

<sup>1</sup> Alfvén Laboratory, Royal Institute of Technology, SE-100 44 Stockholm, Sweden

<sup>2</sup> Stockholm Observatory, SCFAB, SE-106 91 Stockholm, Sweden

E-mail contact: gahm@astro.su.se

New observations show that dark elephant trunks in the Rosette nebula are often built up by thin filaments. In several of the trunks the filaments seem to form a twisted pattern. This pattern is hard to reconcile with current theory. We propose a new model for the formation of twisted elephant trunks in which electromagnetic forces play an important role. The model considers the behaviour of a twisted magnetic filament in a molecular cloud, where a cluster of hot stars has been recently born. As a result of stellar wind and radiation pressures, electromagnetic forces, and inertia forces part of the filament can develop into a double helix pointing towards the stars. The double helix represents the twisted elephant trunk. A simple analogy experiment visualizes and supports the trunk model.

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## Star formation in the bright rimmed globule IC1396N

C. Codella<sup>1</sup>, R. Bachiller<sup>2</sup>, B. Nisini<sup>3</sup>, P. Saraceno<sup>1</sup> and L. Testi<sup>4</sup>

<sup>1</sup> Istituto di Fisica dello Spazio Interplanetario, CNR, Area di Ricerca Tor Vergata, Via Fosso del Cavaliere 100, 00133 Roma, Italy

<sup>2</sup> Observatorio Astronómico Nacional (IGN), Apartado 1143, E-28800, Alcalá de Henares (Madrid), Spain

<sup>3</sup> Osservatorio Astronomico di Roma, Via di Frascati 33, 00040 Monteporzio, Italy

<sup>4</sup> Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy

E-mail contact: codella@ifsu.rm.cnr.it

We report mm-wave multiline and continuum observations of IC1396N, a conspicuous bright rimmed globule excited by the O6.5 star HD206267 in the Cep OB2 association. Single-dish high resolution observations in CO and CS lines reveal the cometary structure of the globule with unprecedented detail. The globule head contains a dense core of 0.2 pc, whereas the tail, pointing away from the exciting star, has a total length of 0.8 pc. Two high velocity bipolar outflows have been identified in the CO maps: the first one is located around the position of a strong IRAS source in the head of the globule, and the second one, which was previously unknown, is located in the northern region. The outflows emerge from high density clumps which exhibit strong line emission of CS, HCO<sup>+</sup>, and DCO<sup>+</sup>. Within these clumps, the sources driving the outflows have been identified thanks to mm-wave continuum observations. The globule head harbors two YSOs separated by about 10<sup>4</sup>AU.

SiO line observations of the central outflow unveils a highly collimated structure with four clumps of sizes  $\leq 0.1$  pc,

which are located along the outflow axis and suggest episodic events in the mass loss process from the central star. Kinetic temperatures of  $\sim 50$ -100 K and hydrogen densities of few  $10^6 \text{ cm}^{-3}$  have been estimated in the shocked regions traced by the strong SiO emission. The jet is also exposed to view by the means of interferometric HCO<sup>+</sup> observations that confirms that it is very narrow ( $\leq 0.02$  pc wide).

The detection of blue- and redshifted CO emission along the globule rim suggests that IC1396N is in a transient phase, undergoing one of the expansions or compressions predicted by theoretical models describing the evolution of cometary globules. Moreover, the CO data, together with near IR observations reported elsewhere, indicate that the star forming process is occurring also in the northern part of IC1396N, at 0.5 pc from the central CS peak. The present observations provide evidence that several star forming sites can develop even in a moderately massive globule like IC1396N.

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## Infall, Outflow, Rotation, and Turbulent Motions of Dense Gas within NGC 1333 IRAS 4

James Di Francesco<sup>1,2</sup>, Philip C. Myers<sup>1</sup>, David J. Wilner<sup>1</sup>, Nagayoshi Ohashi<sup>1,3</sup>, & Diego Mardones<sup>1,4</sup>

<sup>1</sup> Harvard-Smithsonian Center for Astrophysics, 60 Garden St., MS 42, Cambridge, MA 02138 USA

<sup>2</sup> Radio Astronomy Laboratory, 601 Campbell Hall, University of California, Berkeley, Berkeley, CA 94720-3411 USA

<sup>3</sup> Institute of Astronomy and Astrophysics, Academia Sinica, P.O. Box 1-87, Nankang, Taipei 11529, Taiwan, ROC

<sup>4</sup> Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile

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

Millimeter wavelength observations are presented of NGC 1333 IRAS 4, a group of highly-embedded young stellar objects in Perseus, that reveal motions of infall, outflow, rotation, and turbulence in the dense gas around its two brightest continuum objects, 4A and 4B. These data have finest angular resolution of  $\sim 2$  arcsec (0.0034 pc) and finest velocity resolution of  $0.13 \text{ km s}^{-1}$ .

Infall motions are seen from inverse P-Cygni profiles observed in H<sub>2</sub>CO 3<sub>12</sub>-2<sub>11</sub> toward both objects, but also in CS 3-2 and N<sub>2</sub>H<sup>+</sup> 1-0 toward 4A, providing the least ambiguous evidence for such motions toward low-mass protostellar objects. Outflow motions are probed by bright line wings of H<sub>2</sub>CO 3<sub>12</sub>-2<sub>11</sub> and CS 3-2 observed at positions offset from 4A and 4B, likely tracing dense cavity walls. Rotational motions of dense gas are traced by a systematic variation of the N<sub>2</sub>H<sup>+</sup> line velocities, and such variations are found around 4A but not around 4B. Turbulent motions appear reduced with scale, given N<sub>2</sub>H<sup>+</sup> line widths around both 4A and 4B that are narrower by factors of 2 or 3 than those seen from single-dish observations. Minimum observed line widths of  $\sim 0.2 \text{ km s}^{-1}$  provide a new low, upper bound to the velocity dispersion of the parent core to IRAS 4, and demonstrate that turbulence within regions of clustered star formation can be reduced significantly.

A third continuum object in the region, 4B', shows no detectable line emission in any of the observed molecular species.

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Preprint available at <http://cfa-www.harvard.edu/sfgroup/preprints.html>

## A CO Outflow and A Molecular Cloud Core Associated with A Young Massive Star IRAS 22134+5834

Kazuhito Dobashi and Hayato Uehara<sup>1</sup>

<sup>1</sup> Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Koganei, Tokyo 184-8501, Japan

E-mail contact: dobashi@u-gakugei.ac.jp

The purpose of this paper is to present results of the recent <sup>12</sup>CO(J = 1 - 0), <sup>13</sup>CO(J = 1 - 0), and C<sup>18</sup>O(J = 1 - 0) observations carried out toward a bright IRAS point source (22134+5834) using the 45m telescope at Nobeyama Radio Observatory (NRO) equipped with the 4 multi-beam receiver system. The IRAS source exhibits a cold color spectrum in the far infrared wavelengths and has a high luminosity  $\simeq 1700L_{\odot}$  at the adopted distance 900pc, indicating that the IRAS source is a good candidate for an embedded young massive star whose luminosity is equivalent to that of an early B type star having  $\simeq 8M_{\odot}$ .

A bipolar outflow and a dense core associated with IRAS 22134+5834 were detected by the present observations. It is remarkable that the outflow has a very large total molecular mass of  $26M_{\odot}$ , which makes this source one of the most massive outflows reported to date. We derived the dynamical time scale ( $\simeq 7 \times 10^4 \text{yr}$ ), mechanical momentum ( $\simeq 140M_{\odot} \text{kms}^{-1}$ ), and kinetic energy ( $\simeq 400M_{\odot} \text{km}^2 \text{s}^{-2}$ ) of the outflow. The dense core traced in  $\text{C}^{18}\text{O}$  is also massive ( $206M_{\odot}$ ) extending over  $\simeq 1 \text{pc}$ . The core shows an elliptical shape with its major axis inclined by  $-45^{\circ}$  to the north. A velocity gradient of  $0.9 \text{kms}^{-1} \text{pc}^{-1}$  along the core major axis was observed, indicating a rotation of the core. We also detected blue and red velocity-shifted components in  $\text{ceo}$  along the core minor axis separated by  $\simeq 0.7 \text{kms}^{-1}$  from the systemic velocity at  $-18.2 \text{kms}^{-1}$ , which are most likely to trace the mixture of the dense gas being swept up by the powerful outflow and the matter in the core infalling toward the central star.

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## Rapid Formation of Molecular Clouds and Stars in the Solar Neighborhood

Lee Hartmann<sup>1</sup>, Javier Ballesteros-Paredes<sup>2</sup> and Edwin A. Bergin<sup>1</sup>

<sup>1</sup> Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

<sup>2</sup> American Museum of Natural History, 79th St. at Central Park W., New York, NY 10024; also Instituto de Astronomia, UNAM

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

We show how molecular clouds in the solar neighborhood might be formed and produce stars rapidly enough to explain stellar population ages, building on results from numerical simulations of the turbulent interstellar medium and general considerations of molecular gas formation. Observations of both star-forming regions and young, gas-free stellar associations indicate that most nearby molecular clouds form stars only over a short time span before dispersal; large-scale flows in the diffuse interstellar medium have the potential for forming clouds sufficiently rapidly, and for producing stellar populations with ages much less than the lateral crossing times of their host molecular clouds. We identify four important factors for understanding rapid star formation and short cloud lifetimes. First, much of the accumulation and dispersal of clouds near the solar circle might occur in the atomic phase; only the high-density portion of a cloud's lifecycle is spent in the molecular phase, thus helping to limit molecular cloud "lifetimes". Second, once a cloud achieves a high enough column density to form  $\text{H}_2$  and  $\text{CO}$ , gravitational forces become larger than typical interstellar pressure forces; thus star formation can follow rapidly upon molecular gas formation and turbulent dissipation in limited areas of each cloud complex. Third, typical magnetic fields are not strong enough to prevent rapid cloud formation and gravitational collapse. Fourth, rapid dispersal of gas by newly-formed stars, passing shock waves, and reduction of shielding by a small expansion of the cloud after the first events of star formation, might limit the length of the star formation epoch and the lifetime of a cloud in its molecular state. This picture emphasizes the importance of large-scale boundary conditions for understanding molecular cloud formation; implies that star formation is a highly dynamic, rather than quasi-static, process; and that the low galactic star formation rate is due to low efficiency rather than slowed collapse in local regions.

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<http://cfa-www.harvard.edu/cfa/youngstars/publications.html>

## Neutral Atomic Carbon in Intermediate-Velocity Clouds

Andreas Heithausen, Axel Weiß, Jürgen Kerp, Thomas Fritz

Radioastronomisches Institut der Universität Bonn, Auf dem Hügel 71, 53121 Bonn, Germany

E-mail contact: heith@astro.uni-bonn.de

Using the Heinrich-Hertz-Telescope we have detected for the first time the  $[\text{CI}] \ ^3P_1 \rightarrow \ ^3P_0$  line transition at 492 GHz of neutral atomic carbon from two intermediate-velocity clouds (IVCs): IVC 135+54-46 and the Draco Nebula. Both clouds are located at high galactic altitudes, more than 200 pc above the Galactic Plane. The width of the  $[\text{CI}]$  line is quantitatively comparable to that of the  $^{12}\text{CO}$  rather than to that of the  $^{13}\text{CO}$  line, as commonly found for Galactic Plane clouds. This indicates that neutral atomic carbon within the diffuse medium at high galactic altitudes fills a significant larger volume in comparison to the situation in dark or denser cirrus clouds close to the Galactic Plane. Moreover, our observations suggest that for IVCs cooling by the  $[\text{CI}]$  line is as important as or even more important

than that by the low level CO lines. PDR models used to approximate the observed line intensity ratios indicate that the molecular gas in high altitude IVCs is exposed to a weak interstellar radiation field while its density must be high.

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## Magnetic field diagnostics based on far infrared polarimetry: tests using numerical simulations

**F. Heitsch<sup>1</sup>, E.G. Zweibel<sup>2</sup>, M.-M. Mac Low<sup>3</sup>, P.S. Li<sup>4</sup>, & M.L. Norman<sup>4</sup>**

<sup>1</sup> MPI-Heidelberg, Königstuhl 17, D-69117 Heidelberg, Germany

<sup>2</sup> JILA, U. Colorado, Boulder, CO 80309, USA

<sup>3</sup> American Museum of Natural History, New York 10024-5192, USA

<sup>4</sup> LCA, Univ. of Illinois at Urbana-Champaign, IL 61801, USA

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

The dynamical state of star-forming molecular clouds cannot be understood without determining the structure and strength of their magnetic fields. Measurements of polarized far-infrared radiation from thermally aligned dust grains are used to map the orientation of the field and estimate its strength, but the accuracy of the results has remained in doubt. In order to assess the reliability of this method, we apply it to simulated far-infrared polarization maps derived from three-dimensional simulations of supersonic magnetohydrodynamical turbulence, and compare the estimated values to the known magnetic field strengths in the simulations. We investigate the effects of limited telescope resolution and self-gravity on the structure of the maps. Limited observational resolution affects the field structure such that small scale variations can be completely suppressed, thus giving the impression of a very homogeneous field. The Chandrasekhar-Fermi method of estimating the mean magnetic field in a turbulent medium is tested, and we suggest an extension to measure the rms field. Both methods yield results within a factor of 2 for field strengths typical of molecular clouds, with the modified version returning more reliable estimates for slightly weaker fields. However, neither method alone works well for very weak fields, missing them by a factor of up to 150. Taking the geometric mean of both methods estimates even the weakest fields accurately within a factor of 2.5. Limited telescope resolution leads to a systematic overestimation of the field strengths for all methods. We discuss the effects responsible for this overestimation and show how to extract information on the underlying (turbulent) power spectrum.

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## Measurements of the magnetic field geometry and strength in Bok globules

**Th. Henning<sup>1</sup>, S. Wolf<sup>2</sup>, R. Launhardt<sup>3</sup> and R. Waters<sup>4</sup>**

<sup>1</sup> Astrophysikalisches Institut und Universitäts-Sternwarte, Schillergässchen 2-3, D-07745 Jena, Germany

<sup>2</sup> Thüringer Landessternwarte Tautenburg, Sternwarte 5, D-07778 Tautenburg, Germany

<sup>3</sup> Division of Physics, Mathematics and Astronomy, California Institute of Technology, MS 105-24, Pasadena, CA 91125, U.S.A.

<sup>4</sup> Astronomical Institute, University of Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands

E-mail contact: wolf@tls-tautenburg.de

In order to study the influence and structure of the magnetic field in the early phases of low-mass star formation, we obtained polarization maps of three Bok globules at a wavelength of  $850\ \mu\text{m}$ , using the Submillimeter Common-User Bolometer Array (SCUBA) at the James Clerk Maxwell Telescope (JCMT). We observed the following sources: CB 26 - a globule with a nearly dispersed dense core containing a source with a circumstellar disk, CB 54 - a deeply embedded young stellar cluster, and DC 253-1.6 (CG 30) - a protostellar double core.

We find strongly aligned polarization vectors in the case of CB 26 and DC 253-1.6, while the vector orientations in the case of CB 54 are more or less randomly distributed. The degree of polarization, amounting to several percent, was found to decrease toward the center in each source. In the case of CB 54 and DC 253-1.6, the polarization degree similarly depends on the corresponding intensity. Assuming dichroic emission by aligned non-spherical grains as the polarization mechanism, where the magnetic field plays a role in the alignment process, we derive magnetic field strengths and structures from the observed polarization patterns.

In the case of the double core DC 253-1.6, we discuss the correlation between the fragmentation process and the magnetic field direction.

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<http://www1.tls-tautenburg.de/html/publics.htm>

## Gas-phase SO<sub>2</sub> in absorption towards massive protostars

J. V. Keane<sup>1</sup>, A. M. S. Boonman<sup>2</sup>, A. G. G. M. Tielens<sup>1,3</sup> and E. F. van Dishoeck<sup>2</sup>

<sup>1</sup> Kapteyn Institute, P.O. Box 800, NL-9700 AV Groningen, the Netherlands

<sup>2</sup> Leiden Observatory, P.O. Box 9513, NL-2300 RA Leiden, the Netherlands

<sup>3</sup> SRON, P.O. Box 800, NL-9700 AV Groningen, the Netherlands

E-mail contact: jacquie@astro.rug.nl

We present the first detection of the  $\nu_3$  ro-vibrational band of gas-phase SO<sub>2</sub> in absorption in the mid-infrared spectral region around 7.3  $\mu\text{m}$  of a sample of deeply embedded massive protostars. Comparison with model spectra shows that the derived excitation temperatures correlate with previous C<sub>2</sub>H<sub>2</sub> and HCN studies, indicating that the same warm gas component is probed. The SO<sub>2</sub> column densities are similar along all lines of sight suggesting that the SO<sub>2</sub> formation has saturated, but not destroyed, and the absolute abundances of SO<sub>2</sub> are high ( $\sim 10^{-7}$ ). Both the high temperature and the high abundance of the detected SO<sub>2</sub> are not easily explained by standard hot core chemistry models. Likewise, indicators of shock induced chemistry are lacking.

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## Amplification, Saturation, and $Q$ Thresholds for Runaway: Growth of Self-Gravitating Structures in Models of Magnetized Galactic Gas Disks

Woong-Tae Kim and Eve C. Ostriker

Department of Astronomy, University of Maryland, College Park, MD 20742, USA

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

We investigate the susceptibility of gaseous, magnetized galactic disks to formation of self-gravitating condensations using two-dimensional, local models. We focus on two issues: (1) determining the threshold condition for gravitational runaway, taking into account nonlinear effects, and (2) distinguishing the magneto-Jeans instability (MJI) that arises under inner-galaxy rotation curves from the modified swing amplification (MSA) that arises under outer-galaxy rotation curves. For axisymmetric density fluctuations, instability is known to require a Toomre parameter  $Q < 1$ . For nonaxisymmetric fluctuations, any nonzero shear  $q \equiv -d \ln \Omega / d \ln R$  winds up wavefronts such that in linear theory amplification saturates. Any  $Q$  threshold for nonaxisymmetric gravitational runaway must originate from nonlinear effects. We use numerical magnetohydrodynamic simulations to demonstrate the anticipated threshold phenomenon, to analyze the nonlinear processes involved, and to evaluate the critical value  $Q_c$  for stabilization. We find  $Q_c \sim 1.2 - 1.4$  for a wide variety of conditions, with the largest values corresponding to nonzero but subthermal mean magnetic fields. Our findings for  $Q_c$  are similar to those inferred from thresholds for active star formation in the outer regions of spiral galaxies. MJI is distinct from MSA in that opposition to Coriolis forces by magnetic tension, rather than cooperation of epicyclic motion with kinematic shear, enables nonaxisymmetric density perturbations to grow. We suggest that under low-shear inner-disk conditions,  $Q_c$  will be larger than that in outer disks by a factor  $\sim (v_A/qc_s)^{1/2}$ , where  $v_A$  and  $c_s$  are the respective Alfvén and sound speeds.

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Preprints available at <http://www.arXiv.org/abs/astro-ph/0105375>

Associated movies in Animated GIF format available at <http://www.astro.umd.edu/~kimwt/MOVIES/>

## Interferometric Mapping of Magnetic Fields in Star-forming Regions I. W51 e1/e2 Molecular Cores

Shih-Ping Lai<sup>1</sup>, Richard M. Crutcher<sup>1</sup>, José M. Girart<sup>1,2</sup>, and Ramprasad Rao<sup>1,3</sup>

<sup>1</sup> Astronomy Department, University of Illinois, 1002 W. Green Street, Urbana, IL 61801, U.S.A

<sup>2</sup> current address: Departament d'Astronomia i Meteorologia, Universitat de Barcelona, 08028 Barcelona, Catalunya, Spain

<sup>3</sup> current address: Department of Physics, University of Chicago, U.S.A.

E-mail contact: slai@astro.uiuc.edu

We present the first interferometric polarization map of the W51 e1/e2 molecular cores obtained with the BIMA array at 1.3 mm wavelength with approximately 3'' resolution. The polarization angle varies smoothly across the double cores with an average position angle of  $23^\circ \pm 5^\circ$  for W51 e1 and  $15^\circ \pm 7^\circ$  for W51 e2. The inferred magnetic field direction is parallel to the minor axis of the double cores, which is consistent with the theoretical picture that clouds collapse along the field lines. However, the magnetic field may not determine the axis of angular momentum of these two cores as the field directions of the two cores significantly differ with the previously measured directions of rotational axes. The polarization percentage decreases toward regions with high intensity, suggesting that the dust alignment efficiency decreases toward high density regions. The field directions are highly ordered, and the small dispersion of the polarization angles implies that magnetic fields are strong ( $\geq 1$  mG) and perhaps dominate turbulence in W51 e1/e2.

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## Keck NIRC observations of planetary-mass candidate members in $\sigma$ Orionis

**E. L. Martín<sup>1</sup>, M. R. Zapatero Osorio<sup>2</sup>, D. Barrado y Navascués<sup>3</sup>, V. J. S. Béjar<sup>4</sup>, and R. Rebolo<sup>4</sup>**

<sup>1</sup> Institute of Astronomy, Univ. of Hawaii at Manoa, 2680 Woodlawn Drive, Honolulu, HI 96822, U.S.A.

<sup>2</sup> Div. of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, U.S.A.

<sup>3</sup> Universidad Autónoma de Madrid, E-28049 Madrid, Spain

<sup>4</sup> Instituto de Astrofísica de Canarias, E-38200 La Laguna, Tenerife, Spain

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

We present *K*-band photometry and low-resolution near-infrared spectroscopy from 1.44 to 2.45  $\mu\text{m}$  of isolated planetary-mass candidate members in the  $\sigma$  Orionis cluster found by Zapatero Osorio et al. The new data have been obtained with NIRC at the Keck I telescope. All of our targets, except for one, are confirmed as likely cluster members. Hence, we also confirm that the planetary-mass domain in the cluster is well populated. Using our deep *K*-band images we searched for companions to the targets in the separation range 0.3'' to 10'' up to a maximum faint limit of  $K=19.5$  mag. One suspected companion seems to be an extremely red galaxy. The near-infrared colors of the  $\sigma$  Orionis substellar members indicate that dust grains condense and settle in their atmospheres. We estimate that the surface temperatures range from 2500 K down to 1500 K. The spectroscopic sequence covers the full range of L subclasses, and the faintest object is tentatively classified as T0. These targets provide a sequence of substellar objects of known age, distance and metallicity, which can be used as benchmark for understanding the spectral properties of ultracool dwarfs.

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*Text and figures available at:* <http://arXiv.org/abs/astro-ph/?0108066>

*also at:* <http://www.gps.caltech.edu/mosorio/publications.html>

## Evidence for Circumstellar Disks around Young Brown Dwarfs in the Trapezium Cluster

**August Muench<sup>1,3</sup>, Joao Alves<sup>2</sup>, Charles Lada<sup>3</sup> and Elizabeth Lada<sup>1</sup>**

<sup>1</sup> Department of Astronomy, University of Florida, Gainesville, FL 32611, USA

<sup>2</sup> European Southern Observatory, Karl-Schwarzschild-Strasse 2, 85748 Garching, Germany

<sup>3</sup> Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

E-mail contact: muench@astro.ufl.edu

We report the results of deep infrared observations of brown dwarf candidates in the Trapezium cluster in Orion. Analysis of the JHK color-color diagram indicates that a large fraction ( $\sim 65\% \pm 15\%$ ) of the observed sources

exhibit infrared excess emission. This suggests the extreme youth of these objects and in turn, provides strong independent confirmation of the existence of a large population of substellar objects in the cluster. Moreover, this suggests that the majority of these substellar objects are presently surrounded by circumstellar disks similar to the situation for the stellar population of the cluster. This evidence for a high initial disk frequency ( $> 50\%$ ) around cluster members of all masses combined with the smooth continuity of the cluster's initial mass function across the hydrogen burning limit suggests that a single physical mechanism is likely responsible for producing the entire cluster mass spectrum down to near the deuterium burning limit. The results may also indicate that even substellar objects are capable of forming with systems of planetary companions.

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## **X-ray Desorption of Molecules from Grains in Protoplanetary Disks**

**Joan Najita<sup>1</sup>, Edwin A. Bergin<sup>2</sup>, and Joel N. Ullom<sup>3</sup>**

<sup>1</sup> NOAO, 950 N. Cherry Ave, Tucson, AZ 85719, USA

<sup>2</sup> Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

<sup>3</sup> Lawrence Livermore National Laboratory, 7000 East Ave., MS L418, Livermore, CA 94550, USA

E-mail contact: [ebergin@cfa.harvard.edu](mailto:ebergin@cfa.harvard.edu)

We examine the ability of stellar X-rays to desorb molecules from grains in outer protoplanetary disks. In particular, we consider the possibility of spot heating by X-rays and examine its effectiveness, compared to whole grain heating by X-rays, in sustaining a gas phase abundance of CO. As found in previous studies, whole grain heating is effective only for small grains ( $< 500\text{\AA}$ ). As a result, large grains are a permanent sink of CO and whole grain heating cannot sustain an equilibrium gas phase abundance of CO. Spot heating, in which the incident X-ray deposits energy in only a restricted region of the grain volume and which may occur as a consequence of the aggregate nature of grains, proves to be more promising. Assuming that grains are comprised of many thermal subunits that are poorly connected thermally, we find that spot heating is efficient at all grain sizes if large grains are effectively “coated” with small grains  $< 100\text{\AA}$  in size. We discuss the implications of X-ray spot heating for the interpretation of millimeter emission line studies of outer protoplanetary disks.

Accepted by the Astrophysical Journal

Preprint available at <http://xxx.lanl.gov/abs/astro-ph/0108055> or <http://cfa-www.harvard.edu/~ebergin>

## **Exploring Brown Dwarf Disks**

**A. Natta and L. Testi**

Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy

E-mail contact: [natta@arcetri.astro.it](mailto:natta@arcetri.astro.it)

We discuss the spectral energy distribution of three very low mass objects in Chamæleon I for which ground-based spectroscopy and photometry as well as ISO measurements in the mid-infrared are available (Comerón et al. 2000; Persi et al. 2000). One of these stars (Cha H $\alpha$ 1) is a bona-fide brown dwarf, with mass 0.04–0.05  $M_{\odot}$ . We show that the observed emission is very well described by models of circumstellar disks identical to those associated to T Tauri stars, scaled down to keep the ratio of the disk-to-star mass constant and to the appropriate stellar parameters. This result provides a first indication that the formation mechanism of T Tauri stars (via core contraction and formation of an accretion disk) extends to objects in the brown dwarf mass range.

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<http://www.arcetri.astro.it/~starform/publ2001.htm>

## **High mass Class I sources in M 17**

**Markus Nielbock<sup>1,2</sup>, Rolf Chini<sup>2</sup>, Marcus Jütte<sup>2</sup> and Eva Manthey<sup>2</sup>**

<sup>1</sup> SEST, European Southern Observatory, Casilla 19001, Santiago 19, Chile

<sup>2</sup> Astronomisches Institut der Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum, Germany

E-mail contact: mnielboc@eso.org

The region of M 17 has been imaged at 10.5 and 20.0  $\mu\text{m}$  with the groundbased infrared camera MANIAC. In addition to a prominent diffuse emission bar ( $4.5' \times 0.3'$ ) extending southeast to northwest at the interface between the HII region and the southwestern molecular cloud, the mosaic of 133 single frames at each wavelength revealed 22 compact sources. One of these sources is the Kleinmann–Wright–Object and another was previously identified as the ultra-compact HII region M 17-UC1. Combining the *N*-band and *Q*-band data with near infrared data yielded spectral energy distributions that classifies all sources to be of Class I. The observed luminosities were between 55 and 4775  $L_{\odot}$ , which suggests that these sources represent the youngest generation of massive early type stars in M 17 and are surrounded by relics of their protostellar clouds. The morphology of the 10.5 and 20.0  $\mu\text{m}$  emission towards some of the sources reveals flattened structures and may be the first evidence of the presence of circumstellar disks around massive stars.

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<http://www.astro.ruhr-uni-bochum.de/nielbock/research/m17.ps.gz>

## Multiple H<sub>2</sub> protostellar jets in the bright-rimmed globule IC1396-N

B. Nisini<sup>1</sup>, F. Massi<sup>2</sup>, F. Vitali<sup>1</sup>, T. Giannini<sup>1</sup>, D. Lorenzetti<sup>1</sup>, A. Di Paola<sup>1</sup>, C. Codella<sup>3</sup>, F. D’Alessio<sup>1</sup> and R. Speziali<sup>1</sup>

<sup>1</sup> Osservatorio Astronomico di Roma, I-00040 Monteporzio Catone, Italy

<sup>2</sup> Osservatorio Astronomico di Collurania-Teramo, Via M. Maggini, I-64100 Teramo, Italy

<sup>3</sup> CNR-Istituto di Fisica dello Spazio Interplanetario, Area di Ricerca Tor Vergata, Via Fosso del Cavaliere 100, I-00133 Roma, Italy

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

We present near infrared images of the bright rimmed globule IC1396-N in the H<sub>2</sub> 2.12  $\mu\text{m}$  narrow band filter as well as in broad band *J*, *H* and *K* filters. We detected several chains of collimated H<sub>2</sub> knots inside the globule, having different luminosities but similar orientations in the sky. Most of the knots are associated with peaks of high velocity CO emission, indicating that they trace shocked regions along collimated stellar jets. From the H<sub>2</sub> knots morphology and orientation, we identify at least three different jets: one of them is driven by the young protostar associated with IRAS21391+5802, which represents the most luminous object in the region, while we were able to identify only one of the two other driving sources by means of near infrared photometry. Our photometry reveals the existence of a cluster of young embedded sources located in a south-north line which follows the distribution of the high density gas and testifies for a highly efficient star formation activity through all the globule.

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Preprint available at <http://www.mporzio.astro.it/~bruni/publ.html>

## Deep CHANDRA X-RAY OBSERVATORY imaging study of the very young stellar cluster IC 348

Thomas Preibisch<sup>1</sup> and Hans Zinnecker<sup>2</sup>

<sup>1</sup> Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

<sup>2</sup> Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany

E-mail contact: preib@mpifr-bonn.mpg.de

We have obtained a deep (53 ksec) X-ray image of the very young stellar cluster IC 348 with the Advanced CCD Imaging Spectrometer on board the *Chandra X-Ray Observatory*. In our image with a sensitivity limit of  $\sim 1 \times 10^{28}$  erg/sec (more than 10 $\times$  deeper than our ROSAT images of IC 348), 215 X-ray sources are detected. While 115 of these sources can be identified with known cluster members, 58 X-ray sources are most likely new, still unidentified cluster members. About 80% of all known cluster members with masses between  $\sim 0.15 M_{\odot}$  and  $2 M_{\odot}$  are visible as X-ray sources in our image. We discover X-ray emission at levels of  $\sim 10^{28}$  erg/sec from 4 of 13 known brown dwarfs and

from 3 of 12 brown dwarf candidates in IC 348. We also detect X-ray emission from two deeply embedded objects, presumably class I protostars, south of the cluster center.

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Preprints are available at <http://www.mpifr-bonn.mpg.de/staff/tpreibis/publications.html>

## High-resolution near-infrared study of the deeply embedded young stellar object S140 IRS 3

Thomas Preibisch<sup>1</sup>, Yuri Balega<sup>2</sup>, Dieter Schertl<sup>1</sup>, Michael D. Smith<sup>3</sup>, Gerd Weigelt<sup>1</sup>

<sup>1</sup> Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany

<sup>2</sup> Special Astrophysical Observatory, Nizhnij Arkhyz, Zelenchuk region, Karachai-Cherkesia, 357147, Russia

<sup>3</sup> Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland

E-mail contact: [preib@mpifr-bonn.mpg.de](mailto:preib@mpifr-bonn.mpg.de)

We explore the structures immediately surrounding the high-mass young stellar object S140 IRS 3 within the L1204 molecular cloud. We have obtained a bispectrum speckle interferometric  $K$ -band image with a resolution of 150 mas and a seeing-limited molecular hydrogen line emission image of IRS 3. Our speckle image resolves IRS 3 into three point sources, a close binary with separation  $0.63''$  and a third component  $1.3''$  away. A rough assessment of the system stability suggests that the IRS 3 triple system is unstable. Our speckle image also reveals extended diffuse emission of very complex morphology around IRS 3. An extended diffuse feature north-east of IRS 3 displays a remarkable S-shaped structure. This feature is the innermost part of an at least  $15''$  long extended structure, which is pointing towards a bow-shock like patch located  $90''$  away from IRS 3. We find strong  $H_2$  line emission associated with this feature, suggesting the presence of shocks, caused by the collision of outflowing material with the ambient medium. The S-shaped structure of this feature can be well reproduced by a model assuming a precessing outflow from IRS 3a. Furthermore, we find several elongated features pointing away from IRS 3 in a southern direction. Some of these features also exhibit strong  $H_2$  line emission, demonstrating that IRS 3 drives outflows in several directions.

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<http://www.mpifr-bonn.mpg.de/div/speckle/publications.html> or

<http://www.mpifr-bonn.mpg.de/staff/tpreibis/publications.html>

## Large scale ionization of the Radio Arc region by the Quintuplet and the Arches clusters

Nemesio J. Rodríguez-Fernández, Jesús Martín-Pintado, Pablo de Vicente

Observatorio Astronómico Nacional, Apdo 1143, E28800 Alcalá de Henares, Spain

E-mail contact: [nemesio@oan.es](mailto:nemesio@oan.es)

We present an analysis of selected fine structure lines (NeII  $12.8\ \mu\text{m}$ , NeIII  $15.6\ \mu\text{m}$ , SIII  $18.7$  and  $33.5\ \mu\text{m}$ , OIII  $52$  and  $88\ \mu\text{m}$ , NII  $122\ \mu\text{m}$  and NIII  $57\ \mu\text{m}$ ) observed with the *Infrared Space Observatory* (ISO) toward the Radio Arc in the Galactic center region (GCR). Most of the data were retrieved from the ISO Data Archive. We study the density of the ionized gas and the large scale ionization structure in a region of  $\sim 30 \times 30\ \text{pc}^2$  by means of the OIII  $52\ \mu\text{m}/88\ \mu\text{m}$ , SIII  $18.7\ \mu\text{m}/33.5\ \mu\text{m}$ , NeIII  $15.6\ \mu\text{m}/\text{NeII}\ 12.8\ \mu\text{m}$  and NIII  $57\ \mu\text{m}/\text{NII}\ 122\ \mu\text{m}$  line ratios. The electron densities ( $n_e$ ) derived from the OIII lines ratio indicate the presence of diffuse ionized material with  $n_e$  of  $\sim 10^{1.8-2.6}\ \text{cm}^{-3}$ . The NeIII  $15.6\ \mu\text{m}/\text{NeII}\ 12.8\ \mu\text{m}$  and NIII  $57\ \mu\text{m}/\text{NII}\ 122\ \mu\text{m}$  line ratios vary from source to source from 0.05 to 0.30 and from 0.3 to 2.5, respectively. The NIII  $57/\text{NII}\ 122\ \mu\text{m}$  ratio show two clear gradients, one pointing toward the Quintuplet cluster and the other pointing toward the Arches cluster. We have used a simple model to explain the ionization structure observed in the NIII/NII and NeIII/NeII lines ratios. The model shows that the large scale ionization of the whole region can be accounted for by the UV radiation produced by the Quintuplet and the Arches cluster. Any other ionization mechanism should play a minor role. We also investigate the influence of the clusters on the bubble of warm dust (hereafter Radio Arc Bubble, RAB) seen in the *Midcourse Space Experiment* (MSX) infrared images. We find that the warm dust is well correlated with the ionized gas indicating that the dust is also heated by the radiation from both clusters. Furthermore, the elliptical rather than circular symmetry of some structures like the Thermal Filaments can also be explained when one considers the combined effects of both the Arches and the Quintuplet clusters. We have also found that the RAB is filled with continuum emission of hard X rays and with emission from the  $6.4\ \text{keV}$  line of neutral or low ionized Fe. We briefly discuss the implications of these findings on

the structure and morphology of the GCR interstellar medium and the possible origin of the RAB.

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## Kinematics of Herbig-Haro objects and jets in the Orion Nebula

Margarita Rosado<sup>1</sup>, Eduardo de la Fuente<sup>1,4</sup>, Lorena Arias<sup>1</sup>, Alejandro Raga<sup>2</sup> and Ettiane Le Coarer<sup>3</sup>

<sup>1</sup> Instituto de Astronomía, UNAM, Apdo. Postal 70-264, 04510 México, D. F., México

<sup>2</sup> Instituto de Ciencias Nucleares, UNAM, Apdo. Postal 70-543, 04510 México, D. F., México

<sup>3</sup> Observatoire de Grenoble, BP53X Grenoble CEDEX, France

<sup>4</sup> Facultad de Ciencias, UNAM, México, D. F., México

E-mail contact: margarit@astroscu.unam.mx

We have surveyed the inner 5' of the Orion Nebula by means of H $\alpha$  and [NII] Fabry-Perot imaging spectroscopy to present a kinematical study of the Herbig-Haro objects in the nebula. The objects studied in this work are HH 202, 203, 204, 529, 269 and other associated features. For HH 202 we find new features that, because of their high velocities (up to 100 km s<sup>-1</sup>) indicate the presence of an outflow that probably is a HH flow not catalogued previously. HH 202 could be only a part of this larger outflow. Large internal motions are found in the fainter regions of HH 203-204, as well as evidence of transverse density gradients that could account for the asymmetry in the brightness distribution of HH 204. We report for the first time a high blueshifted velocity (-118 km s<sup>-1</sup>) associated with HH 204, and show that the apex of HH 204 is indeed the zone of maximum velocity, in agreement with bow shock models. We also studied the radial velocity field of HH 269 finding features associated with the HH object. From our studies, we find kinematic evidence that suggests that HH 203-204 and HH 202 are part of a big ( $\sim 0.55$  pc) bipolar HH outflow.

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## Heating and Ionization of X-Winds

Hsien Shang<sup>1,2,3</sup>, Al E. Glassgold<sup>1,4</sup>, Frank H. Shu<sup>1</sup>, and Susana Lizano<sup>5</sup>

<sup>1</sup> Astronomy Department, University of California, Berkeley, CA 94720, USA

<sup>2</sup> Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

<sup>3</sup> Institute of Astronomy and Astrophysics, Academia Sinica, Taipei, Taiwan

<sup>4</sup> Physics Department, New York University, NY 10003, USA

<sup>5</sup> Instituto de Astronomía, UNAM, 58090 Morelia, Michoacán, México

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

In order to compare the x-wind with observations, one needs to be able to calculate its thermal and ionization properties. We formulate the physical basis for the streamline-by-streamline integration of the ionization and heat equations of the steady x-wind. In addition to the well-known processes associated with the interaction of stellar and accretion-funnel hot-spot radiation with the wind, we include X-ray heating and ionization, mechanical heating, and a revised calculation of ambipolar diffusion heating. The mechanical heating arises from fluctuations produced by star-disk interactions of the time dependent x-wind that are carried by the wind to large distances where they are dissipated in shocks, MHD waves, and turbulent cascades. We model the time-averaged heating by the scale-free volumetric heating rate,  $\Gamma_{\text{mech}} = \alpha \rho v^3 s^{-1}$ , where  $\rho$  and  $v$  are the local mass density and wind speed, respectively,  $s$  is the distance from the origin, and  $\alpha$  is a phenomenological constant. When we consider a partially-revealed but active young stellar object, we find that choosing  $\alpha \sim 10^{-3}$  in our numerical calculations produces temperatures and electron fractions that are high enough for the x-wind jet to radiate in the optical forbidden lines at the level and on the spatial scales that are observed. We also discuss a variety of applications of our thermal-chemical calculations that can lead to further observational checks of x-wind theory.

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# Chandra Detection of a Close X-ray Companion and Rich Emission Line Spectrum in the Wolf-Rayet Binary $\gamma$ Velorum

Stephen L. Skinner<sup>1</sup>, Manuel Güdel<sup>2</sup>, Werner Schmutz<sup>3</sup>, and Ian R. Stevens<sup>4</sup>

<sup>1</sup> CASA, Univ. of Colorado, Boulder, CO 80309-0389 USA

<sup>2</sup> Paul Scherrer Institute, Würenlingen and Villigen, CH-5235 Switzerland

<sup>3</sup> Physikalisch-Meteorologisches Observatorium Davos, Dorfstrasse 33, CH-7260 Davos Dorf, Switzerland

<sup>4</sup> School of Physics and Astronomy, Univ. of Birmingham, Birmingham B15 2TT, UK

E-mail contact: [skinners@casa.colorado.edu](mailto:skinners@casa.colorado.edu)

We present first results of a high-resolution X-ray observation of the nearby Wolf-Rayet binary system  $\gamma^2$  Velorum (WC8 + O7.5) using the *Chandra* High Energy Transmission Grating (HETG). Emission lines from Mg, Si, S, Ne, and Fe dominate the spectrum and imply a range of plasma temperatures from  $\sim 4$  MK up to at least  $\sim 25$  MK. The strongest lines are broadened but no Doppler shifts are detected. He-like triplets show strong forbidden lines with no significant weakening from collisional effects or photoexcitation, contrasting sharply with the diluted forbidden lines of single O-type supergiants such as  $\zeta$  Puppis. These results imply that some lines such as the Ne IX triplet are formed in cooler plasma at tens of stellar radii or more from the O star, well outside of the central wind interaction region located near the O star surface. Lastly, we report the discovery of a new X-ray source lying only  $4.''8$  north of  $\gamma^2$  Vel that is very likely a low mass *pre-main-sequence* star.

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Preprints: <ftp://origins.colorado.edu>, username: ftp, password: your e-mail, cd pub/skinners/, binary, get gvel\_final.ps.gz

## X-ray emission from young stars in Taurus-Auriga-Perseus: Luminosity functions and the rotation - activity - age - relation

B. Stelzer<sup>1</sup> and R. Neuhäuser<sup>1</sup>

<sup>1</sup> Max-Planck-Institut für extraterrestrische Physik, Postfach 1312, D-85741 Garching, Germany

E-mail contact: [stelzer@mpe.mpg.de](mailto:stelzer@mpe.mpg.de)

We report on a systematic search for X-ray emission from pre-main sequence and young main sequence stars in the Taurus-Auriga-Perseus region. Our stellar sample consists of all T Tauri stars from the Taurus-Auriga region, and all late-type stars from the Pleiades and Hyades clusters which have been observed by the *ROSAT* PSPC in pointed observations. We present the X-ray parameters for all observed stars in tables. Next to the basic results of the data analysis (such as count rates, exposure time, and off-axis angle) we give X-ray luminosities and hardness ratios for all detected stars. Upper limits are given for non-detections. Detection rates for different spectral types are compiled. We use these results to study the connection between coronal X-ray activity and stellar parameters for different subgroups of our sample. In particular we compile X-ray luminosity functions (XLF), and discuss the relations between X-ray emission and spectral type, age, and rotation, which have been disputed extensively in the past. Here, we study these questions with the largest sample so far. The XLF for classical and weak-line T Tauri stars are different, with weak-lines being the stronger X-ray emitters. Proceeding towards the main-sequence (Pleiades, Hyades) the X-ray luminosity declines for all spectral types examined (G, K, and M stars). Within an age group  $L_x$  decreases towards later spectral types, while  $L_x/L_{\text{bol}}$  remains constant or even increases, reflecting the opposed influence of stellar radius, i.e. emitting area, and convection zone depth. For a given spectral type the fastest rotators show the highest X-ray luminosity. Rotation rate and X-ray emission are clearly correlated for all groups of stars with power law indices for  $\lg(L_x/L_{\text{bol}})$  versus  $\lg P_{\text{rot}}$  of  $\sim -0.7$  to  $-1.5$ . The study of XLF for binary stars shows that the known unresolved secondaries likely contribute a significant amount to the X-ray emission.

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<http://www.xray.mpe.mpg.de/~stelzer/publications.html>

## Mass ratios of the components in T Tauri binary systems and implications for multiple star formation

Jens Woitas<sup>1</sup>, Christoph Leinert<sup>2</sup> and Rainer Köhler<sup>3</sup>

<sup>1</sup> Thüringer Landessternwarte Tautenburg, Sternwarte 5, 07778 Tautenburg, Germany

<sup>2</sup> Max-Planck-Institut für Astronomie, Königstuhl 17, 69117 Heidelberg, Germany

<sup>3</sup> Center for Astrophysics and Space Sciences, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0424, USA

E-mail contact: [woitas@tls-tautenburg.de](mailto:woitas@tls-tautenburg.de)

Using near-infrared speckle interferometry we have obtained resolved JHK-photometry for the components of 58 young binary systems. From these measurements, combined with other data taken from literature, we derive masses and particularly mass ratios of the components.

We use the J-magnitude as an indicator for the stellar luminosity and assign the optical spectral type of the system to the primary. On the assumption that the components within a binary are coeval we can then place also the secondaries into the HRD and derive masses and mass ratios for both components by comparison with different sets of current theoretical pre-main sequence evolutionary tracks. The resulting distribution of mass ratios is comparatively flat for  $M_2/M_1 \geq 0.2$ , but depends on assumed evolutionary tracks. The mass ratio is neither correlated with the primary's mass or the components' separation. These findings are in line with the assumption that for most multiple systems in T associations the components' masses are principally determined by fragmentation during formation and not by the following accretion processes.

Only very few unusually red objects were newly found among the detected companions. This finding shows that the observed overabundance of binaries in the Taurus-Auriga association compared to nearby main sequence stars should be real and not the outcome of observational biases related to infrared observing.

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<http://www.tls-tautenburg.de/research/tls-research/pub2001.html>

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## *Dissertation Abstracts*

# **Circumstellar Environments and Activity in Young and Evolved Stars**

**Joana M. Oliveira**

Thesis work conducted at: Solar System Division, ESTEC/ESA, The Netherlands and  
Centro de Astrofísica da Universidade do Porto, Portugal

Current address: Astrophysics Group, Department of Physics, Keele, Staffordshire ST5 5BG, United Kingdom

Electronic mail: joana@astro.keele.ac.uk

Ph.D dissertation directed by: B.H. Foing and M.T.V.T. Lago

Ph.D degree awarded: June 2001

The main goal behind my thesis research is to investigate activity and variability in two very distinct types of stars and circumstellar environments: the giant ultra-fast rotator FK Comae and the T Tauri star SU Aurigae.

One of the most useful tools in activity and variability studies is the analysis of spectroscopic time series. Not only a well-sampled continuous time series is required, also a large wavelength range is essential in order to describe the different physical conditions throughout the atmosphere. In this context the multi-site MUSICOS campaigns and the MUSICOS echelle spectrographs were decisive in gathering the data sets analysed here. Specific echelle data reduction techniques were applied to the MUSICOS data. The FK Comae data sets were mostly obtained with the MUSICOS spectrographs, during the commissioning of the ESA-MUSICOS instrument at the Isaac Newton Telescope in La Palma, and at the T elescope Bernard Lyot in France. The data set on SU Aurigae was obtained at five telescopes during the MUSICOS 1996 campaign; this data set is unique both in terms of time sampling and phase coverage. I applied specific analysis techniques (e.g. profile decomposition and cross-correlation analysis) to quantify the observed multi-line variability. As one of the organisers, I describe the goals, preparation and execution of the successful MUSICOS 1998 campaign. For both FK Comae and SU Aurigae, I also analyse polarimetric observations aimed at detecting magnetic fields in these stars.

FK Comae is an evolved giant star, with high rotation rate and extreme activity. The Balmer excess emission and the He I D3 profiles are analysed. I used a multi-component technique to identify several velocity components in H $\alpha$  and H $\beta$  which were traced in phase. From the H $\alpha$  time series, I constructed a two dimensional emission map using a back-projection technique. The results of the present analysis indicate that the excess emission arises from the near-circumstellar environment, probably from prominence-like structures locked in co-rotation with the stellar surface by magnetic fields. These structures have strong intrinsic variability, but they seem to be stable for at least a few rotation periods.

The study of the disk-star interaction in T Tauri stars is essential to understand their activity and circumstellar environment. Both accretion and outflows play a role in the formation of emission lines. I analysed some SU Aurigae line profiles (H $\alpha$ , H $\beta$ , Na I D and He I D3) in order to constrain the geometry and dynamics of its magnetosphere. Different time lags were found between the accretion signatures, and I suggest that this time-lagged behaviour can occur if the magnetic field lines in the oblique magnetosphere are azimuthally distorted. Plasma outflows, powered by the disruption of the magnetic field lines, might be the cause of the transient absorption features also present in the data set.

In order to probe the outer circumstellar environment of SU Aurigae, its spectral energy distribution is modelled, from ultra-violet to radio wavelengths. I used two distinct approaches to model the circumstellar excess emission: a disk in hydrostatic and radiative equilibrium, and a spherically symmetric dust envelope with a cavity where resides a flat blackbody disk. Both the shell and disk dimensions clearly indicate a very extended circumstellar matter distribution. Both models provide good agreement to the spectral energy distribution and cannot be distinguished with the limited observational data available.

The unique and new data sets presented here allowed to address problems and constrain models of chromospheric (magnetic) activity and of magnetospheric coupling with circumstellar environments of two classes of stars. I discuss the perspectives for follow up on this research, with the next generation of telescopes and instruments, on the ground and in space.

## *New Jobs*

### POSTDOCTORAL POSITIONS

#### INSTITUTO DE ASTRONOMIA UNIVERSIDAD NACIONAL AUTONOMA DE MEXICO

The Instituto de Astronomía-UNAM, México, expects to have two openings for postdoctoral fellows beginning in October 2001. The positions are for one year with the possibility of renewal for a second year, and with residence in either Mexico City (one position) or Morelia, Michoacán (one position). The Institute has an active staff involved in most branches of astrophysical research. Research programmes include theory, observations, and instrumentation development. The Instituto de Astronomía, has a network of workstations and provides the following research facilities:

\* The Observatorio Astronómico Nacional at San Pedro Mártir, Baja California and at Tonantzintla, Puebla with telescopes of 2.1m, 1.5m, 0.84m and 1m.

\* Access to the UNAM's Supercomputers (CRAY and Origin 2000).

Positions are open for recent Ph.D.'s in Physics and Astronomy, independent of nationality. Candidates interested in collaborating with staff members in the fields of **Interstellar Medium**, **Star Formation** or **Stellar Atmospheres** are encouraged to apply. Outstanding candidates in related fields will also be considered. Applicants should include a curriculum vitae, with a list of publications, two letters of recommendation, and a statement of their research interests and goals. The deadline for applications is the **30th of August 2001**.

Please direct inquiries and send all documents to: **José Franco** or **Gloria Koenigsberger**, Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510, México, D.F., or to their e-mail addresses

**pepe@astroscu.unam.mx**, **gloria@astroscu.unam.mx**.

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://casa.colorado.edu/reipurth> or at <http://www.eso.org/gen-fac/pubs/starform/>.

## *New Books*

### **Disks, Planetesimals, and Planets**

Editors **F. Garzón, C. Eiroa, D. de Winter, & T.J. Mahoney**

These are the proceedings of a conference held in Tenerife, Spain 24-28 January 2000. The book summarizes the latest results on the structure and evolution of circumstellar disks around young stars, theoretically as well as observed at multiple wavelengths, the role of planetesimals and dust around main sequence stars, and the rapidly developing field of exoplanets.

The following lists the Invited Review articles in the book. Numerous Contributed Talks and poster papers are included as well.

#### **Part 1. From Disks to Planets**

*From Disks to Planets: An Overview* A.P. Boss

*Disk Evolution towards Planet Formation* C. Terquem et al.

#### **Part 2. Pre-Main Sequence Stars**

*Observational Aspects of Protostellar Disks* P.T.P. Ho

*Accretion Disks* L. Hartmann

*Images of Protoplanetary Disks from Millimeter to Near-Infrared Wavelengths* A. Dutrey

#### **Part 3. The Pre-Main Sequence and Main Sequence**

*Disks and Planets in Binary Systems* W. Kley & A. Burkert

*Infall, Accretion, and the Spectroscopic Evidence for Planetesimals* C.A. Grady et al.

*Photopolarimetric Activity of Pre-Main Sequence Stars* V.P. Grinin

*ISO Observations of Pre-Main Sequence and Vega-Type Stars* M.E. van den Ancker

*Mid-Infrared Observations of Disks* C.M. Telesco

*Sub-Millimeter Studies of Dusty Debris around Nearby Stars* J.S. Greaves & W.S. Holland

*Models of  $\beta$  Pictoris and Disks around Main-Sequence Stars* A. Lecavelier des Etangs

#### **Part 4. Exoplanets**

*Mass Function and Distributions of the Orbital Elements of Substellar Companions* M. Mayor & S. Udry

*Late Planetesimal Delivery and the Composition of Giant Planets* T. Guillot & B. Gladman

*Chemical Abundance Trends among Stars with Planets* G. Gonzalez

*Detecting Planets using Transit Observations* T.M. Brown

#### **Part 5. Future Projects**

*Planet Detection from the Ground: Can the VLTI Help?* V. Coude du Foresto

*The ALMA Project* S. Guilloteau

*Infrared Space Interferometry - The DARWIN Mission* C.V.M. Fridlund

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# From Dust to Terrestrial Planets

Editors W. Benz, R. Kallenbach and G.W. Lugmair

These are the proceedings of a meeting held in Bern Switzerland 15-19 February 1999, and which originally appeared in *Space Science Reviews* volume 92, Nos. 1-2, 2000. The workshop was organized as a series of invited review talks, which aimed at presenting a detailed assessment of the currently available astronomical, chronological, geochemical and dynamical constraints of the first period of inner solar system evolution. Thus, the book presents an overview of the events and processes that led from a molecular cloud more than 4.6 billion years ago to the planetary system that some 100 million years later had almost reached its present appearance. The book contains the following articles:

## I. Disk Formation, Stability, and Evolution

*Triggering Protostellar Collapse, Injection, and Disk Formation* A.P. Boss & H. Vanhale  
*Protostellar Disk Formation and Early Evolution* F.C. Adams & G. Laughlin  
*Solar Nebula Magnetohydrodynamics* S.A. Balbus & J.F. Hawley  
*Observational Constraints on Transport (and Mixing) in pre-Main Sequence Disks* L. Hartmann  
*Beta Pictoris and Other Solar Systems* P. Artymowicz  
*Temperature and Pressure Gradients in the Solar Nebula* J.A. Wood

## II. Formation of Compounds and First Solids

*The Beginning: Swift and Violent* J.A. Wood  
*Short-lived Radionuclides in Meteorites: Constraints on Nebular Timescales for the Production of Solids* R.H. Nicholls  
*The Extinct Radionuclide Timescale of the Early Solar System* J.D. Gilmour  
*Short-lived Radioactivities and the Birth of the Sun* B.S. Meyer & D.D. Clayton  
*Protostellar Winds and Chondritic Meteorites* H. Shang et al.  
*Kinetics of Gas-grain Reactions in the Solar Nebula* B. Fegley  
*The Solar System D/H ratio: Observations and Theories* F. Robert et al.  
*On the  $^{53}\text{Mn}$  Heterogeneity in the Early Solar Nebula* A. Shukolyukov & G.W. Lugmair  
*Are there Chemical Gradients in the Inner Solar System?* H. Palme

## III. Formation of Planetesimals and Planetary Embryos

*Laboratory Experiments on Preplanetary Dust Aggregation* J. Blum  
*Low Velocity Collisions and the Growth of Planetesimals* W. Benz  
*Formation of Planetesimals and Accretion of the Terrestrial Planets* S.J. Weidenschilling  
*Planetary Accumulation with a Continuous Supply of Planetesimals* G.W. Wetherill & S. Inaba

## IV. Formation and Evolution of Planets

*Disks, Extrasolar Planets, and Migration* C. Terquem et al.  
*An Oxygen Isotope mixing Model for the Accretion and Composition of Rocky Planets* K. Lodders  
*Hf-W Chronometry and Inner Solar System Accretion Rates* A.N. Halliday  
*On the Isotopic Composition of primordial Xenon in Terrestrial Planet Atmospheres* R.O. Pepin  
*minor Bodies: Spectral Gradients and Relationships with Meteorites* A. Cellino

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